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ning of each regular issue of the PCT Gazette.*

(54) Title: FLAX SEED SPECIFIC PROMOTERS

(57) Abstract: Novel methods for the expression of non-native genes in flax seeds and the seeds of other plant species are provided. The methods involve the use of seed-specific promoters obtained from flax. Additionally provided are novel flax seed-specific promoters, chimeric nucleic acid constructs comprising novel flax seed-specific promoters, transgenic plant cells, transgenic plants and transgenic plant seeds containing novel flax seed-specific promoters. The promoters and methods are useful, for example, for altering the seed oil and protein composition in flax seed or other plant seeds.

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Title: Flax Seed Specific Promoters

FIELD OF THE INVENTION

The present invention relates to plant genetic engineering methods useful for the alteration of the constituents of plant seeds. More specifically, the invention relates to promoters that have been obtained from flax and are capable of directing expression of non-native genes in flax seeds as well as the seeds of other plants.

BACKGROUND OF THE INVENTION

Flax or linseed (*Linum usitatissimum*) is a commercially important oilseed crop. Flax oil and meal are valuable raw materials derived from flax seed. A further economically significant raw material, flax fiber, is obtainable from the stem of the plant. The flax oil fraction is used for non-edible purposes, for example in the manufacture of varnish and paint, and has more recently become suited for use in the manufacture of a range of edible products, such as margarines and salad oils and dressings, by virtue of newly bred so called Linola cultivars (Green (1986) Can. J. Plant Sci, 66: 499-503). Flax meal is used primarily as a constituent of ruminant feeds while flax fibers are used in the manufacture of linen fabrics. Given its economic importance as a source for raw materials, it is desirable to further improve and diversify the available flax cultivar portfolio both with respect to agronomic performance, for example seed yield, resistance to pathogens and low climatic temperatures, and with respect to yield and quality of the raw materials to suit downstream applications. Although it is possible to obtain improved flax cultivars through conventional plant breeding, as evidenced by the development of the Linola cultivars, developing an elite agronomic plant line requires large investments in plant breeding due to the long timelines involved. Plant genetic engineering technology allows the isolation of genes directly from unrelated species and the transfer of these genes into elite agronomic backgrounds, thereby significantly reducing the time required to develop new cultivars. In addition plant genetic engineering permits the manufacture of products not naturally obtainable from flax, for example therapeutic agents.

In order to develop novel flax cultivars through plant genetic engineering, control over the expression of the introduced foreign or non-native gene is of critical importance. The desired expression characteristics for the non-native gene, such as the level of expression of the non-native gene, the particular plant tissue or organ in which the non-native gene is expressed, and the particular time in the growth cycle of the plant at which the non-native gene is expressed, will vary depending on the application for which the plant line is developed. For example, the modification of the seed oil composition may require low levels of seed-specific expression of an enzyme involved in fatty acid metabolism at an early stage in seed development (see for example US Patent 5,420,034). On the other hand expression of a pharmaceutical protein could preferably require high

levels of leaf-specific expression upon harvesting of the plant leaves (see for example, US Patent 5,929,304).

In order to manipulate the expression characteristics of non-native genes numerous factors can be influenced. One factor is the choice of the transcriptional promoter used. A wide range of plant compatible promoters is currently available and some of the better documented promoters include constitutive promoters such as the 35-S CaMV promoter (Rothstein *et al.* (1987), Gene 53: 153-161) and the ubiquitin promoter (US Patent 5,614,399), tissue specific promoters such as seed-specific promoters, for example the phaseolin promoter (Sengupta-Gopalan *et al.*, (1985), PNAS USA 82: 3320-3324) and inducible promoters, such as those inducible by heat (Czarnencka *et al.*, (1989), Mol. Cell. Biol. 9 (8): 3457-3464), UV light, elicitors and wounding (Lois *et al.*, (1989) EMBO J. 8 (6): 1641-1648), or chemicals such as endogenous hormones (Skriver *et al.* (1991), Proc. Natl. Acad. Sci. USA 88(16): 7266-7270). Other factors that can be manipulated in order to control the expression characteristics of non-native gene in plants include transcriptional modification factors such as introns, polyadenylation sites and transcription termination sites. The expression characteristics of the non-native gene can further be manipulated by factors that affect translation, such as ribosomal binding sites and the codon bias that is exhibited by the host. Furthermore, the non-native gene itself may affect the viability of the transgenic plant, thus limiting particularly the levels of expression that can be attained. In some cases it may be possible to overcome this problem, by expressing the protein in a tissue specific manner, e.g. in the leaves or seed, or by restricting the accumulation of the protein in different subcellular compartments such as for example the cytoplasm, the endoplasmic reticulum or vacuoles, typically by the presence or the absence of specific targeting sequences capable of directing the protein to these compartments. Another factor that will affect the expression characteristics is the location in which the construct inserts itself into the host chromosome. This effect could provide an explanation as to why different plants, transformed with the same recombinant construct, can have fluctuating levels of recombinant protein expression.

To the best of the inventors' knowledge, expression of non-native genes in flax seeds is only documented in PCT Patent Application WO 98/18948. This application discloses two stearyl-acyl carrier protein desaturase (SAD) genes derived from flax. The associated SAD promoter sequences are useful for the modification of flax and other plants for the expression of endogenous or foreign genes. However the methods taught by WO 98/18948 are limited by the fact that the SAD promoters are not seed-specific in flax and confer expression to leaves, stems, flowers and seeds. Expression of non-native genes thus may result in undesirable side effects in non-seed tissues. In addition the use of the SAD promoters allows limited control over expression level and timing of expression.

There is a need in the art to further improve methods for the expression of non-native genes in flax seeds and other plant seeds.

SUMMARY OF THE INVENTION

The present invention relates to improved methods for the seed-specific
5 expression of non-native genes in plants. In particular, the invention relates to improved methods for the seed-specific expression of non-native genes in flax.

Accordingly, in one aspect, the invention provides a method for the expression of a nucleic acid sequence of interest in flax seeds comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3'
10 direction of transcription as operably linked components
 - (1) a seed-specific promoter obtained from flax; and
 - (2) the nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said flax seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
15 (c) growing said flax plant cell into a mature flax plant capable of setting seed, wherein said nucleic acid sequence of interest is expressed in the seed under the control of said flax seed-specific promoter.

In a preferred embodiment of the invention, at least one expression characteristic, e.g. timing of expression in the plant's life cycle, conferred by the promoter to the
20 non-native nucleic acid sequence is similar to that expression characteristic when conferred to a native nucleic acid sequence. In further preferred embodiments, the flax seed-specific promoter is an oleosin promoter, a 2S storage protein promoter or a legumin-like seed storage protein promoter.

In a further aspect, the present invention provides transgenic flax seeds prepared
25 according to a method comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3'
direction of transcription as operably linked components:
 - (1) a seed-specific promoter obtained from flax; and
 - (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is
30 non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
- (c) growing said flax plant cell into a mature flax plant capable of setting seed, wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.

In a further aspect the present invention provides flax plants capable of setting
35 seed prepared by a method comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3'
direction of transcription as operably linked components:

- (1) a seed-specific promoter obtained from flax; and
- (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
- 5 (c) growing said flax plant cell into a mature flax plant capable of setting seed, wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.

In yet a further aspect, the present invention provides novel flax seed specific promoters useful for the expression of non-native genes in flax seeds and the seeds of other
10 plant species, useful for example for modification of the protein or oil composition of the seed.

In a preferred embodiment, the seed specific promoter comprises:

- (a) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be
15 U;
- (b) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (a);
- (c) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a) or (b);
- 20 (d) a nucleic acid sequence that is an analog of a nucleic acid sequence of (a), (b) or (c); or
- (e) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a), (b), (c) or (d) under stringent hybridization conditions.

In another aspect, the invention provides chimeric nucleic acid sequences
25 comprising a first nucleic acid sequence obtained from flax operatively linked to a second nucleic acid sequence non-native to said first nucleic acid sequence wherein said first nucleic acid sequence comprises a novel flax seed-specific promoter.

Other features and advantages of the present invention will become readily apparent from the following detailed description. It should be understood, however, that
30 the detailed description and the specific examples while indicating preferred embodiments of the invention are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art of this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

35 The invention will now be described in relation to the drawings in which:

Figure 1 shows the DNA sequence (SEQ.ID.NO.:1) of a flax genomic clone encoding a 16.0 kDa oleosin protein (SEQ.ID.NOS.:2 and 3).

Figure 2 shows the DNA sequence (SEQ.ID.NO.:4) of a flax genomic clone encoding a 18.6 kDa oleosin protein (SEQ.ID.NO.:5).

Figure 3 shows the DNA sequence (SEQ.ID.NO.:6) of a flax genomic clone encoding a 2S storage protein (SEQ.ID.NO.:7).

5 Figure 4 shows the DNA sequence (SEQ.ID.NO.:8) of a flax genomic clone encoding a 54.5 kDa legumin-like storage protein (SEQ.ID.NOS.:9-12).

Figure 5 shows Southern blot analysis of flax genomic DNA probed with flax oleosin DNA sequences.

10 Figure 6 shows a Northern blot analysis of the seed specific expression of flax oleosins.

Figure 7 shows a Northern blot analysis of the developmental expression of flax oleosins during seed development.

Figure 8 shows the GUS activity of flax embryos bombarded with flax oleosin promoter-GUS-flax terminator gene constructs.

15 Figure 9 shows GUS expression in developing flax embryos and Arabidopsis seeds of plants transformed with a 2S protein gene promoter GUS fusion.

Figure 10 shows the tissue-specific expression of GUS in transgenic flax plants transformed with a linin promoter-GUS-linin terminator gene construct.

20 Figure 11 shows the temporal expression of GUS in transgenic flax plants transformed a linin promoter-GUS-linin terminator gene construct.

Figure 12 shows the expression of GUS in transgenic *Brassica napus* plants (L1 to L9) transformed with a linin promoter-GUS-linin terminator gene construct.

25 Figure 13 shows the expression of GUS in transgenic Arabidopsis plants transformed with a linin promoter-GUS-linin terminator gene construct at different stages of seed development.

DETAILED DESCRIPTION OF THE INVENTION

As hereinbefore mentioned, the present invention relates to improved methods for the expression of non-native genes in plants, in particular flax. The invention provides methods allowing the seed-specific expression of non-native genes in flax. The methods of
30 the invention are advantageous in that improved control over the expression of non-native genes in flax seeds is obtained. Expression of the non-native gene is restricted to the seeds, thereby limiting potential undesirable effects resulting from the expression in other plant organs or tissues. In addition, the provided methodology allows improved control over expression characteristics, such as the expression level of the non-native gene and timing of
35 expression of the non-native gene in the developmental cycle of the plant. The methods of the present invention are particularly useful in that in accordance with the present invention the seed composition with respect to valuable raw materials, such as oil, protein and polysaccharides, may be altered both qualitatively and quantitatively.

Accordingly, in one aspect, the invention provides a method for the expression of a nucleic acid sequence of interest in flax seeds comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3' direction of transcription as operably linked components;
 - 5 (1) a seed-specific promoter obtained from flax; and
 - (2) the nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said flax seed-specific promoter;
 - (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
 - (c) growing said flax plant cell into a mature plant capable of setting seed,
- 10 wherein said nucleic acid sequence of interest is expressed in the seed under the control of said flax seed-specific promoter.

As used herein, the term "non-native" refers to any nucleic acid sequence, including any RNA or DNA sequence, which is not normally associated with the seed-specific promoter. This includes heterologous nucleic acid sequences which are
15 obtained from a different plant species as the promoter as well as homologous nucleic acid sequences which are obtained from the same plant species as the promoter but are not associated with the promoter in the wild-type (non-transgenic) plant.

The non-native nucleic acid sequence when linked to a seed-specific promoter obtained from flax results in a chimeric construct. The chimeric construct is introduced into a
20 flax plant cell to create a transgenic flax plant cell which results in a detectably different phenotype of the flax plant cell or flax plant grown from it when compared with a non-transgenic flax plant cell or flax plant grown from it. A contiguous nucleic acid sequence identical to the nucleic acid sequence of the chimeric construct is not present in the non-transformed flax plant cell or flax plant grown from it. In this respect, chimeric nucleic
25 acid sequences include those sequences which contain a flax promoter linked to a nucleic acid sequence obtained from another plant species or a nucleic acid sequence from flax but normally not associated with that promoter. Chimeric nucleic acid sequences as used herein further include sequences comprising a flax promoter and a nucleic acid sequence that is normally linked to the promoter but additionally containing a non-native nucleic acid
30 sequence. For example, if the promoter is a flax seed-specific oleosin promoter, sequences "non-native" to the flax oleosin promoter also include a sequence comprising a fusion between the flax oleosin gene naturally associated with the oleosin promoter, and a coding sequence of interest that is not naturally associated with the promoter. The term non-native is also meant to include a fusion gene as hereinabove which additionally
35 includes a cleavage sequence separating the nucleic acid sequence that is normally linked to the promoter sequence and the gene encoding the protein of interest.

The term "nucleic acid sequence" refers to a sequence of nucleotide or nucleoside monomers consisting of naturally occurring bases, sugars and intersugar (backbone) linkages.

The term also includes modified or substituted sequences comprising non-naturally occurring monomers or portions thereof, which function similarly. The nucleic acid sequences of the present invention may be ribonucleic (RNA) or deoxyribonucleic acids (DNA) and may contain naturally occurring bases including adenine, guanine, cytosine, thymidine and uracil. The sequences may also contain modified bases such as xanthine, hypoxanthine, 2-aminoadenine, 6-methyl, 2-propyl, and other alkyl adenines, 5-halo uracil, 5-halo cytosine, 6-aza uracil, 6-aza cytosine and 6-aza thymine, pseudo uracil, 4-thiouracil, 8-halo adenine, 8-amino adenine, 8-thiol adenine, 8-thio-alkyl adenines, 8-hydroxyl adenine and other 8-substituted adenines, 8-halo guanines, 8-amino guanine, 8-thiol guanine, 8-thioalkyl guanines, 8-hydroxyl guanine and other 8-substituted guanines, other aza and deaza uracils, thymidines, cytosines, adenines, or guanines, 5-trifluoromethyl uracil and 5-trifluoro cytosine.

The term "seed-specific promoter", means that a gene expressed under the control of the promoter is predominantly expressed in plant seeds with no or no substantial expression, typically less than 5% of the overall expression level, in other plant tissues.

In a further aspect, the present invention provides novel flax seed specific promoters useful for the expression of non-native genes in flax seeds and the seeds of other plant species. The promoters may be used to modify for example the protein, oil or polysaccharide composition of the seeds. In a preferred embodiment, the seed specific promoter comprises:

- (a) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be U;
- (b) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (a);
- (c) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a) or (b);
- (d) a nucleic acid sequence that is an analog of a nucleic acid sequence of (a), (b) or (c); or
- (e) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a), (b), (c) or (d) under stringent hybridization conditions.

The term "sequence that has substantial sequence homology" means those nucleic acid sequences which have slight or inconsequential sequence variations from the sequences in (a) or (b), i.e., the sequences function in substantially the same manner and are capable of driving seed specific expression of non-native nucleic acid sequences. The variations may be attributable to local mutations or structural modifications. Nucleic acid sequences having substantial homology include nucleic acid sequences having at least 65%, more preferably at least 85%, and most preferably 90-95% identity with the nucleic acid sequences as shown in

Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8).

The term "sequence that hybridizes" means a nucleic acid sequence that can hybridize to a sequence of (a), (b), (c) or (d) under stringent hybridization conditions.

5 Appropriate "stringent hybridization conditions" which promote DNA hybridization are known to those skilled in the art, or may be found in Current Protocols in Molecular Biology, John Wiley & Sons, N.Y. (1989), 6.3.1-6.3.6. For example, the following may be employed: 6.0 x sodium chloride/sodium citrate (SSC) at about 45°C, followed by a wash of 2.0 x SSC at 50°C. The stringency may be selected based on the conditions used in the wash step. For
10 example, the salt concentration in the wash step can be selected from a high stringency of about 0.2 x SSC at 50°C. In addition, the temperature in the wash step can be at high stringency conditions, at about 65°C.

The term "a nucleic acid sequence which is an analog" means a nucleic acid sequence which has been modified as compared to the sequence of (a), (b) or (c) wherein the
15 modification does not alter the utility of the sequence (i.e. as a seed specific promoter) as described herein. The modified sequence or analog may have improved properties over the sequence shown in (a), (b) or (c). One example of a modification to prepare an analog is to replace one of the naturally occurring bases (i.e. adenine, guanine, cytosine or thymidine) of the sequence shown in Figure 1, Figure 2, Figure 3 or Figure 4 with a modified base such as
20 such as xanthine, hypoxanthine, 2-aminoadenine, 6-methyl, 2-propyl and other alkyl adenines, 5-halo uracil, 5-halo cytosine, 6-aza uracil, 6-aza cytosine and 6-aza thymine, pseudo uracil, 4-thiouracil, 8-halo adenine, 8-aminoadenine, 8-thiol adenine, 8-thiolalkyl adenines, 8-hydroxyl adenine and other 8-substituted adenines, 8-halo guanines, 8 amino guanine, 8-thiol guanine, 8-thiolalkyl guanines, 8-hydroxyl guanine and other
25 8-substituted guanines, other aza and deaza uracils, thymidines, cytosines, adenines, or guanines, 5-trifluoromethyl uracil and 5-trifluoro cytosine.

Another example of a modification is to include modified phosphorous or oxygen heteroatoms in the phosphate backbone, short chain alkyl or cycloalkyl intersugar linkages or short chain heteroatomic or heterocyclic intersugar linkages in the nucleic acid
30 molecule shown in Figure 1, Figure 2, Figure 3 or Figure 4. For example, the nucleic acid sequences may contain phosphorothioates, phosphotriesters, methyl phosphonates, and phosphorodithioates.

A further example of an analog of a nucleic acid molecule of the invention is a peptide nucleic acid (PNA) wherein the deoxyribose (or ribose) phosphate backbone in the
35 DNA (or RNA), is replaced with a polyamide backbone which is similar to that found in peptides (P.E. Nielsen, et al Science 1991, 254, 1497). PNA analogs have been shown to be resistant to degradation by enzymes and to have extended lives *in vivo* and *in vitro*. PNAs also bind stronger to a complimentary DNA sequence due to the lack of charge repulsion

between the PNA strand and the DNA strand. Other nucleic acid analogs may contain nucleotides containing polymer backbones, cyclic backbones, or acyclic backbones. For example, the nucleotides may have morpholino backbone structures (U.S. Pat. No. 5,034,506). The analogs may also contain groups such as reporter groups, a group for
5 improving the pharmacokinetic or pharmacodynamic properties of nucleic acid sequence.

In another aspect, the invention provides chimeric nucleic acid sequences comprising a first nucleic acid sequence obtained from flax operatively linked to a second nucleic acid sequence non-native to said first nucleic acid sequence wherein said first nucleic acid sequence comprises a novel flax seed-specific promoter. Preferably, the promoter is
10 selected from the group of promoters comprising Figure 1, Figure 2, Figure 3 and Figure 4 or a nucleic acid sequence hybridizing thereto under stringent conditions.

In accordance with the present invention, the chimeric nucleic acid sequences can be incorporated in a known manner in a recombinant expression vector which ensures good expression in the seed cell. Accordingly, the present invention includes a recombinant
15 expression vector comprising a chimeric nucleic acid sequence of the present invention suitable for expression in a seed cell.

The term "suitable for expression in a seed cell" means that the recombinant expression vectors contain the chimeric nucleic acids sequence of the invention, a regulatory region and a termination region, selected on the basis of the seed cell to be used for
20 expression, which is operatively linked to the nucleic acid sequence encoding the polypeptide of desirable amino acid composition. Operatively linked is intended to mean that the chimeric nucleic acid sequence encoding the polypeptide is linked to a regulatory sequence and termination region which allows expression in the seed cell. A typical construct consists, in the 5' to 3' direction of a regulatory region complete with a promoter
25 capable of directing expression in a plant, a polypeptide coding region and a transcription termination region functional in plant cells. These constructs may be prepared in accordance with methodology well known to those of skill in the art of molecular biology (see for example: Sambrook *et al.* (1990), Molecular Cloning, 2nd ed. Cold Spring Harbor Press). The preparation of constructs may involve techniques such as restriction digestion, ligation, gel
30 electrophoresis, DNA sequencing and PCR. A wide variety of cloning vectors is available to perform the necessary cloning steps. Especially suitable for this purpose are the cloning vectors with a replication system that is functional in *Escherichia coli* such as pBR322, the pUC series M13mp series, pACYC184, pBluescript etc. Nucleic acid sequences may be introduced into these vectors and the vectors may be used to transform *E. coli* which may be
35 grown in an appropriate medium. Plasmids may be recovered from the cells upon harvesting and lysing the cells. Final constructs may be introduced into plant vectors compatible with integration into the plant such as the Ti and Ri plasmids.

The methods for the expression of non-native genes in flax seeds in accordance with the present invention may be practiced using any flax seed-specific promoter and are not limited by the specific flax seed specific promoter that is selected. In preferred embodiments of the present invention, the flax seed-specific promoter confers to the non-native nucleic acid sequence at least one expression characteristic which is similar or identical to an expression characteristic conferred to the native nucleic acid sequence by the native promoter. The term "expression characteristic" as used herein refers to any measurable property or effect conferred by the flax seed-specific promoter to the nucleic acid sequence operably linked to the flax seed-specific promoter. Thus in preferred embodiments, timing of expression in the plant's life cycle, of the non-native nucleic acid sequence is similar or identical to timing of expression of the native nucleic acid sequence. In further preferred embodiments, the expression level of the heterologous nucleic acid sequence is similar or identical to the expression level of the native nucleic acid sequence. In yet further specific embodiments, the response of the non-native gene to alterations in lighting conditions, changes in wavelength or light intensity for example, changes in temperature, tissue wounding, changes in concentration of chemical agents, such as for example phytohormones and pesticides, is similar to the response of the native nucleic acid sequence to these stimuli. Other desired expression characteristics conferred by a flax seed-specific promoter may be recognized by those skilled in the art and a flax seed-specific promoter may be selected accordingly.

Flax-seed specific promoters that may be used in accordance with the present invention include promoters associated with seed storage proteins, such as all albumins and globulins, including the vicilin and legumin-like proteins, as well as seed-specific promoters not associated with seed storage proteins, such as oleosins. Of further particular interest are promoters associated with fatty acid metabolism, such as acyl carrier protein (ACP), saturases, desaturases, elongases and the like.

In preferred embodiments of the present invention the seed specific promoter used is an oleosin promoter, a legumin-like seed storage protein promoter or a 2S storage protein promoter. In particularly preferred embodiments the seed specific promoter has the sequence shown in Figure 1, Figure 2, Figure 3 or Figure 4 or any nucleic acid sequences obtainable from flax and hybridizing to any one of these four nucleic acid sequences under stringent conditions.

Additional flax seed-specific promoters may be used in accordance with the present invention. These promoters may be obtained in a number of ways. Where a flax seed protein has been isolated, it may be partially sequenced, so that a nucleic acid probe may be designed for identifying RNA specific to the seed. To further enhance the RNA specifically associated with the seed, cDNA may be prepared from seed cells and the cDNA may be subtracted with mRNA or cDNA from non-seed cells. The remaining seed

cDNA may then be used to probe a genomic DNA library for complementary sequences. Sequences hybridizing to the cDNA may subsequently be obtained and the associated promoter region may be isolated. It is also possible to screen genomic DNA libraries prepared from flax seed tissues using known seed specific genes from other plant species and subsequently isolate their associated promoters. Due to the relative abundance of seed-storage proteins in seeds it is also possible to obtain sequence information through random sequencing of flax seed cDNA libraries. Those cDNA sequences matching sequence of known seed-storage proteins could be used to identify the associated promoter. Databases containing sequence information from large scale sequencing from for example *Arabidopsis* and maize may be searched for known seed-specific proteins and/or promoters and the information may be used to identify promoter sequences in flax that share sequence similarity. Alternative methods to isolate additional flax seed specific promoters may be used and novel flax seed specific promoters may be discovered by those skilled in the art and used in accordance with the present invention.

The nucleic acid sequence of interest linked to the promoter may be any nucleic acid sequence of interest including any RNA or DNA sequence encoding a peptide or protein of interest, for example, an enzyme, or a sequence complementary to a genomic sequence, where the genomic sequence may be at least one of an open reading frame, an intron, a non-coding leader sequence, or any sequence where the complementary sequence will inhibit transcription, messenger RNA processing, for example splicing or translation. The nucleic acid sequence of interest may be synthetic, naturally derived or a combination thereof. As well, the nucleic acid sequence of interest could be a fragment of the natural sequence, for example just include the catalytic domain or a structure of particular importance. Depending upon the nature of the nucleic acid sequence of interest, it may be desirable to synthesize the sequence with plant preferred codons. The plant preferred codons may be determined from the codons of highest frequency in the proteins expressed in the largest amount in particular plant species of interest.

The nucleic acid sequence of interest may encode any of a variety of recombinant proteins. Examples of recombinant proteins which might be expressed by the methods of the present invention include proteins with a favorable catalytic function or a valuable protein that will accumulate to high levels and be extracted if desired. Proteins with a catalytic function, include, but are not limited to, proteins that confer a new biochemical phenotype on the developing seeds. New phenotypes could include such modifications as altered seed-protein or seed oil composition or seed polysaccharide composition, enhanced production of pre-existing desirable products or properties and the reduction or even suppression on an undesirable gene product using antisense, ribozyme or co-suppression technologies (Izant and Weintraub (1984) Cell 26: 1007-1015, antisense; Hazellhoff and

Gerlach (1988) Nature 334: 585-591, ribozyme; Napoli *et al.* (1990) Plant Cell 2: 279-289, co-suppression).

It is expected that the desired proteins would be expressed in all embryonic tissues, although varying cellular expression may be detected in the different embryonic tissues such as the embryonic axis and cotyledons. The nucleic acid sequence of interest may be expressed at any stage in seed development. The timing of expression may depend on the particular use of the invention. Expression of enzymes involved in oil modification may be desirable early in seed development, for example before accumulation of seed storage protein.

Besides the promoter region and the nucleic acid sequence of interest, a nucleic acid sequence capable of terminating transcription is typically included in expression vectors. Transcriptional terminators are preferably about 200 to about 1,000 nucleotide base pairs and may comprise any such sequences functional in plants, such as the nopaline synthase termination region (Bevan *et al.*, (1983) Nucl. Acid. Res. 11: 369-385), the phaseolin terminator (van der Geest *et al.*, (1994) Plant J. 6(3): 413-423), the terminator for the octopine synthase gene of *Agrobacterium tumefaciens* or other similarly functioning elements. These transcription terminator regions can be obtained as described by An (1987), Methods in Enzym. 153: 292 or are already present in plasmids available from commercial sources such as ClonTech, Palo Alto, California. The choice of the appropriate terminator may have an effect of the rate of transcription.

The chimeric construct may further comprise enhancers such as the AMV leader (Jobling and Gehrke (1987), Nature 325: 622-625) or introns. It should be understood that the design of the expression vector may depend on such factors as the choice of the plant species and/or the type of polypeptide to be expressed.

The expression vectors will normally also contain a marker gene. Marker genes comprise all genes that enable distinction of transformed plant cells from non-transformed cells, including selectable and screenable marker genes. Conveniently, a marker may be a resistance marker to a herbicide, for example, glyphosate or phosphinothricin, or to an antibiotic such as kanamycin, G418, bleomycin, hygromycin, chloramphenicol and the like, which confer a trait that can be selected for by chemical means. Screenable markers may be employed to identify transformants through observation. They include but are not limited to the β -glucuronidase or *uidA* gene, a β -lactamase gene or a green fluorescent protein (Niedz *et al.* (1995) Plant Cell Rep. 14: 403).

In order to introduce nucleic acid sequences into plant cells in general a variety of techniques are available to the skilled artisan. *Agrobacterium*-mediated transformation for flax plant cells has been reported and flax transformants may be obtained in accordance with the methods taught by Dong and McHughen (1993) Plant Science 88: 61-77, although a

variety of other techniques (see below) may also be used to introduce the chimeric DNA constructs in flax cells if so desired.

Transformed flax plants grown in accordance with conventional agricultural practices known to a person skilled in the art are allowed to set seed. Flax seed may then be
5 obtained from mature flax plants and analyzed for desired altered properties with respect to the wild-type seed.

Two or more generations of plants may be grown and either crossed or selfed to allow identification of plants and strains with desired phenotypic characteristics including production of the recombinant polypeptide. It may be desirable to ensure
10 homozygosity in the plants to assure continued inheritance of the recombinant trait. Methods for selecting homozygous plants are well known to those skilled in the art of plant breeding and include recurrent selfing and selection and anther and microspore culture. Homozygous plants may also be obtained by transformation of haploid cells or tissues followed by regeneration of haploid plantlets subsequently converted to diploid plants by
15 any number of known means (e.g. treatment with colchicine or other microtubule disrupting agents).

The present invention also includes transgenic flax seeds prepared according to a method comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3'
20 direction of transcription as operably linked components:
- (1) a seed-specific promoter obtained from flax; and
 - (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
25 (c) growing said flax plant cell into a mature flax plant capable of setting seed wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.

In preferred embodiments of the invention the seed-specific promoter is selected from the group of flax seed specific promoters consisting of, a 2S storage protein promoter, a
30 globulin promoter, an oleosin promoter, and a legumin-like seed storage protein promoter. Specific promoter sequences are shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) and Figure 4 (SEQ.ID.NO.:8).

The present invention further provides flax plants capable of setting seed prepared by a method comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3'
35 direction of transcription as operably linked components:
- (1) a seed-specific promoter obtained from flax; and

- (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
- (c) growing said flax plant cell into a mature flax plant capable of setting seed
- 5 wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.

The present invention further provides methods of use for the novel promoters shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) and Figure 4 (SEQ.ID.NO.:8) in plant species other than flax. Accordingly, the invention also

10 includes the preparation of chimeric nucleic acid constructs comprising a promoter selected from the group promoters shown in Figure 1, Figure 2, Figure 3 and Figure 4 and a nucleic acid sequence of interest, and expression in a seed-specific manner of the nucleic acid sequence of interest in plant species other than flax and under the control of the flax promoter.

In another aspect of the present invention there is provided a method for the

15 expression of a nucleic acid sequence of interest in plant seeds comprising:

- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3' direction of transcription as operably linked components;
- (1) a seed-specific promoter selected from the group of seed-specific promoters consisting of
- 20 (i) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be U;
- (ii) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (i);
- 25 (iii) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (i) or (ii); and
- (iv) a nucleic acid sequence that is an analog of a nucleic acid sequence of (i), (ii) or (iii);
- (v) a nucleic acid sequence that hybridizes to a nucleic acid sequence of
- 30 (i), (ii), (iii) or (iv) under stringent hybridization conditions; and
- (2) said nucleic acid of interest;
- (b) introducing the chimeric nucleic acid construct into a plant cell;
- (c) growing said plant cell into a mature plant capable of setting seed, wherein said nucleic acid sequence of interest is expressed in the seed under the control of said
- 35 seed-specific promoter.

A variety of techniques are available for the introduction of nucleic acid sequences, in particular DNA, into plant host cells in general. For example, the chimeric DNA constructs may be introduced into host cells obtained from dicotyledonous plants, such

as tobacco, and oleoagenous species, such as *Brassica napus* using standard *Agrobacterium* vectors by a transformation protocol such as described by Moloney *et al.* (1989), Plant Cell Rep. 8: 238-242 or Hinchee *et al.* (1988) Bio/Technol. 6: 915-922; or other techniques known to those skilled in the art. For example, the use of T-DNA for transformation of plant cells

5 has received extensive study and is amply described in EP 0 120 516, Hoekema *et al.*, (1985), Chapter V In: *The Binary Plant Vector System* Offset-drukkerij Kanters BV, Alblasterdam); Knauf *et al.* (1983), *Genetic Analysis of Host Expression by Agrobacterium*, p. 245, In: *Molecular Genetics of Bacteria-Plant Interaction*, Puhler, A. ed. Springer-Verlag, NY); and An *et al.*, (1985), (EMBO J., 4: 277-284). *Agrobacterium* transformation may also be

10 used to transform monocot plant species (US Patent 5,591,616).

Conveniently, explants may be cultivated with *Agrobacterium tumefaciens* or *Agrobacterium rhizogenes* to allow for the transfer of the transcription construct in the plant host cell. Following transformation using *Agrobacterium* the plant cells are dispersed into an appropriate medium for selection, subsequently callus, shoots and eventually plants

15 are recovered. The *Agrobacterium* host will harbour a plasmid comprising the vir genes necessary for transfer of the T-DNA to plant cells. For injection and electroporation (see below) disarmed Ti-plasmids (lacking the tumour genes, particularly the T-DNA region) may be introduced into the plant cell.

The use of non-*Agrobacterium* techniques permits the use of constructs described

20 herein to obtain transformation and expression in a wide variety of monocotyledonous and dicotyledonous plant species. These techniques are especially useful for transformation of plant species that are intractable in an *Agrobacterium* transformation system. Other techniques for gene transfer include particle bombardment (Sanford, (1988), Trends in Biotechn. 6: 299-302), electroporation (Fromm *et al.*, (1985), PNAS USA, 82: 5824-5828;

25 Riggs and Bates, (1986), PNAS USA 83: 5602-5606), PEG mediated DNA uptake (Potrykus *et al.*, (1985), Mol. Gen. Genetics., 199: 169-177), microinjection (Reich *et al.*, Bio/Techn. (1986) 4:1001-1004) and silicone carbide whiskers (Kaeppeler *et al.* (1990) Plant Cell Rep. 9: 415-418).

In a further specific applications such as to *B. napus*, the host cells targeted to

30 receive recombinant DNA constructs typically will be derived from cotyledonary petioles as described by Moloney *et al.* (1989) Plant Cell Rep. 8: 238-242. Other examples using commercial oil seeds include cotyledon transformation in soybean explants (Hinchee *et al.*, (1988) Bio/Technol. 6: 915-922) and stem transformation of cotton (Umbeck *et al.*, (1987) Bio/Technol. 5: 263-266).

35 Following transformation, the cells, for example as leaf discs, are grown in selective medium. Once the shoots begin to emerge, they are excised and placed onto rooting medium. After sufficient roots have formed, the plants are transferred to soil. Putative transformed plants are then tested for presence of a marker. Southern blotting is performed

on genomic DNA using an appropriate probe, to show integration into the genome of the host cell.

The methods provided by the present invention can be used in conjunction a broad range of plant species. Particularly preferred plant cells employed in accordance with the present invention include cells from the following plants: soybean (*Glycine max*), rapeseed (*Brassica napus*, *Brassica campestris*), sunflower (*Helianthus annuus*), cotton (*Gossypium hirsutum*), corn (*Zea mays*), tobacco (*Nicotiana tabacum*), alfalfa (*Medicago sativa*), wheat (*Triticum* sp.), barley (*Hordeum vulgare*), oats (*Avena sativa* L.), sorghum (*Sorghum bicolor*), *Arabidopsis thaliana*, potato (*Solanum* sp.), flax/linseed (*Linum usitatissimum*), safflower (*Carthamus tinctorius*), oil palm (*Eleais guineensis*), groundnut (*Arachis hypogaea*), Brazil nut (*Bertholletia excelsa*) coconut (*Cocos nucifera*), castor (*Ricinus communis*), coriander (*Coriandrum sativum*), squash (*Cucurbita maxima*), jojoba (*Simmondsia chinensis*) and rice (*Oryza sativa*).

The present invention has a variety of uses which include improving the intrinsic value of plant seeds by their accumulation of altered polypeptides or novel recombinant peptides or by the incorporation or elimination or a metabolic step. Use of the invention may result in improved protein quality (for example, increased concentrations or essential or rare amino acids), improved liquid quality by a modification of fatty acid composition, or improved or elevated carbohydrate composition. Examples include the expression of sulfur-rich proteins, such as those found in lupins or brazil nuts in a seed deficient in sulphurous amino acids. Improved protein quality could also be achieved by the expression of a protein or a fragment of a protein that is enriched in essential amino acids including lysine, cysteine, methionine and tryptophan. Alternatively, a fatty acyl coenzyme A, a transferase enzyme capable of modifying fatty acid ratios in triglycerides (storage lipid) could be expressed. In cases where a recombinant protein is allowed to accumulate in the seed, the protein could also be a peptide which has pharmaceutical or industrial value. In this case the peptide could be extracted from the seed and used in crude or purified form as appropriate for the intended use. As well, the polypeptides that are expressed in the seeds can be fragments or derivatives or the native protein. Pharmaceutically useful proteins may include, but are not limited to, anticoagulants, such as hirudin, antibodies, including monoclonal antibodies and antibody fragments, vaccines, cytokines or growth factors such as bovine growth factor, cholinergic differentiation factor (CDF), ciliary neurotrophic factor (CNTF), fibroblast growth factor (FGF), fish growth factor, gonadotropin, granulocyte-colony stimulating factor (G-CSF), granulocyte-macrophage colony-stimulating factor (GM-CSF), human growth hormone, interferon alpha (IFN- α), interferon beta (IFN- β), interferon gamma (IFN- γ), interleukin 1-alpha (IL1- α), interleukin 1-beta (IL1- β), interleukin-2 (IL-2), interleukin-3 (IL-3), interleukin-4 (IL-4), interleukin-5 (IL-5), interleukin-6 (IL-6), interleukin-10 (IL-10), leukemia inhibitory factor

(LIF), thioredoxin, macrophage colony-stimulating factor (M-CSF), myelomonocytic growth factor, nerve growth factor (NGF), oncostatin M, platelet-derived growth factor (PDGF), prolactin, transforming growth factor alpha (TGF- α), transforming growth factor beta2 (TGF- β 2), tumour necrosis factor alpha (TNF- α), and tumour necrosis factor beta (TNF- β). Pharmaceutically useful proteins can also include mammalian proteins, for example, but not limited to α -1-antitrypsin, anti-obesity proteins, blood proteins, collagen, collagenase, elastin, elastase, enteropeptidase, fibrinogen, haemoglobin, human serum albumin, insulin, lactoferrin, myoglobin and pulmonary surfactant proteins.

Industrially useful peptides may include, but are not limited to α -amylase or other amylases, amyloglucosidase, arabinase, catalase, cellobiohydrolase, cellulases, chitinases, chymotrypsin, dehydrogenases, endo-glucanase, chymosin, endo-galactanase, esterases, β -galactosidase, α -galactosidase or other galactosidases, gastric lipases, glucanases, glucose isomerase, hemi-cellulases, hydrolases, isomerase, ligninases, lipases, lyases, lysozymes, oxidases, oxidoreductase, papain, pectinases, pectin lyase, peroxidases, phosphatases, phytase, proteases, pullulanases, reductases, serine proteases, thioredoxin, transferase, trypsin, and xylanase.

The following non-limiting examples are illustrative of the present invention:

EXAMPLES

EXAMPLE 1

Isolation of Seed-Specific Flax Promoters

Seed specific cDNA clones were isolated from a flax seed specific cDNA-library. These cDNA clones were sequenced and the Basic Local Alignment Search Tool (BLAST) was used to compare these sequences against others in public databases such as Genbank. This comparison revealed that the deduced amino acid sequence of several of the isolated cDNAs had a high degree of similarity to both the low and high molecular weight class of oleosins, 2S-albumin and legumin-like storage proteins. Probes were prepared individually from (portions of) cDNAs encoding oleosins, 2S albumin and legumin-like storage proteins and these were used to screen a genomic library prepared from the flax line Forge that is homozygous for four rust resistance genes (Anderson *et al.* (1997), The Plant Cell 9: 641-651). Several positive lambda clones for each probe were identified after high-stringency screening. The inserts were subcloned into the plasmid vector pBluescript and sequenced. Sequence information revealed that we had isolated the genomic counterparts to the oleosins, 2S albumin and cDNAs *legumin-like* cDNAs. Sequence information of the genomic clones containing sequences encoding a high and low molecular weight oleosin isoforms, 2S albumin and a legumin-like gene are presented in Figures 1 to 4 respectively.

Figure 1 and SEQ.ID.NO.:1 shows the DNA sequence of a flax genomic clone encoding a 16.0 kDa oleosin protein (low molecular weight or L-isoform). Putative regulatory elements are identified and indicated. These include inverted repeats (base

pairs 805 to 813 and 821 to 829; base pairs 1858 to 1866 and 1877 to 1885), direct repeats (base pairs 184 to 193 and 1102 and 1111; base pairs 393 to 402 and 1701 to 1710; base pairs 683 to 692 and 1546 to 1555; base pairs 770 to 781 and 799 to 810; base pairs 955 to 964 and 1936 to 1945; base pairs 1483 to 1496 and 1513 to 1526), the abscisic acid responsive element (ABRE) (base pairs 1859 to 1866), CACA box (base pairs 1933 to 1936), TATA box (base pairs 1925 to 1931) and CAT box (base pairs 1989 to 1993). As well, the poly adenylation signal is indicated (base pairs 3020 to 3025). The open reading frame is interrupted by 1 short intron (which are marked) and the 2 exons are translated and indicated in IUPAC single letter amino-acid codes.

Figure 2 and SEQ.ID.NO.:4 shows the DNA sequence of a flax genomic clone encoding a 18.6 kDa oleosin protein (high molecular weight or H-isoform). Putative regulatory elements are identified and indicated. These include direct repeats (base pairs 14 to 25 and 1427 to 1438; base pairs 80 to 89 and 1242 to 1251; base pairs 177 to 186 and 837 to 846; base pairs 1281 to 1290 and 1242 to 1251; base pairs 1591 to 1600 and 1678 to 1287). The open reading frame is not interrupted by introns and is translated and indicated in IUPAC single letter amino-acid codes.

Figure 3 and SEQ.ID.NO.:6 shows the DNA sequence of the flax genomic clone encoding a 2S storage protein. Nucleotide sequencing of this clone revealed it to have an open reading frame of 174 amino acids that showed homology to the plant 2S storage group of proteins. The sequence encodes an open reading frame with 38% overall similarity to a *Brassica oleracea* 2S storage protein, including complete conservation of the glutamine-rich stretch QQQGQQGQQQ (SEQ.ID.NO.:13). In addition, the 2S storage protein gene promoter contained several putative promoter regulatory elements. These include AT rich repeats (base pairs 25-36, 97-108 and 167-190), RY-like repeat (base pairs 240-247), G-box-like element (base pairs 274-280), seed specific box-like motif (base pairs 285-290) and TATA box (base pairs 327-333).

Figure 4 and SEQ.ID.NO.:8 shows the DNA sequence of a flax genomic clone encoding a 54.4 kDa flax legumin-like seed storage protein. This legumin-like seed storage protein gene will also be referred to as "linin". The deduced amino acid sequence of the linin gene was compared to the *legumin-like* protein from *R. communis*, the legumin precursor from *M. salicifolia*, *Q. robur* and *G. hirsutum*, the glutelin precursor from *O. sativa* and a 12 S seed storage protein from *A. thaliana*. The linin gene shows a sequence identity/similarity with the corresponding proteins from *R. communis*, *M. salicifolia*, *Q. robur*, *G. hirsutum*, *O. sativa* and *A. thaliana* of 59/15, 47/16, 50/17, 45/17, 43/18 and 43/18 percent respectively. Putative regulatory elements in the promoter region are identified and indicated. These include inverted repeats (base pairs 265 to 276 and 281 to 292; base pairs 513 to 524 and 535 to 545), repeats (base pairs 1349 to 1360 and 1367 to 1378; base pairs 1513 to 1529 and 1554 to 1572), the abscisic acid responsive element (ABRE) (base pairs 1223 and

1231), legumin box (RY repeats) (between base pairs 1223 and 1231), a possible vicilin box region (base pairs 1887 to 1894), CAAT box (base pairs 1782 to 1785) and TATA box (base pairs 1966 to 1970). As well, the signal peptide for ER membrane targeting is indicated (base pairs 2034-2080). The open reading frame is interrupted by 3 short introns (which are marked) and the 4 exons are translated and indicated in IUPAC single letter amino-acid codes.

Figure 5 shows Southern blot analysis of flax genomic DNA. 60 µg of flax genomic DNA was isolated from leaves, digested with EcoRI (lane 1), HindIII (lane 2) and BamHI (lane 3) and was loaded into the respective lanes. A) Hybridizations were performed with random primed ³²P-labelled 3T cDNA (high molecular weight flax oleosin isoform). B) Hybridizations were performed with random primed ³²P-labelled 7R cDNA (low molecular weight flax oleosin isoform). The results demonstrate that both 3T (high molecular weight oleosin isoform) and 7R (low molecular weight oleosin isoform) oleosin cDNAs hybridize with flax genomic DNA. More specifically the results indicate that 3T is likely to represent a 2-copy gene in flax, as seen by two bands in each lane of digestion. Similarly, 7R is likely to represent a multigene family in flax as multiple bands were detected for each digestion.

EXAMPLE 2

Seed specific expression of flax oleosin genes

Figure 6 shows a Northern blot analysis of the seed specific expression of flax oleosins. Northern hybridization of the two oleosin mRNA in different tissues. Ten µg of total RNA was extracted from different tissues, R, root; C, cotyledon; L, leaf; S, seed capsule; E, embryo. The membrane was probed with (A) cDNA encoding high molecular weight (H)-isoform (identical to coding sequence as presented in Figure 2) and (B) cDNA encoding low molecular weight (L) -isoform (identical to coding sequence as presented in Figure 1). Both the transcripts are expressed only in the embryo and seed capsule, which contains embryos.

EXAMPLE 3

Developmental expression of flax oleosin genes during seed development

Figure 7 shows a Northern blot analysis of the developmental expression of flax oleosins during seed development. 15 µg per lane of total RNA was loaded in each lane on agarose/formaldehyde gel and blotted onto HybondN+ membrane. 10J: This membrane was probed using the ³²P dCTP labeled flax oleosin cDNA clone (low molecular weight isoform). Stages indicated are the number of days past anthesis (DPA). 3T) 15 µg per lane of total RNA was loaded in each lane on agarose/formaldehyde gel and blotted onto HybondN+ membrane. 3T: This membrane was probed using the ³²P dCTP labeled flax oleosin cDNA clone (high molecular weight isoform). Both the transcripts were expressed very early in

development (6DPA, early cotyledonary stage). Expression is maximum at 16 to 20 DPA (late cotyledonary stage) and declines at 22 DPA (mature embryos).

EXAMPLE 4

Transient Seed specific expression of β -glucuronidase (GUS) when under the regulatory control of flax oleosin regulatory sequences

Two constructs were made using standard molecular biology techniques (eg see Sambrook *et al.* (1990), Molecular Cloning, 2nd ed. Cold Spring Harbor Press, including restriction enzyme digestions, ligation and polymerase chain reaction (PCR).

Construct pSC54: The β -glucuronidase reporter coding sequence from vector GUSN358>S (Clontech Laboratories) was placed between the promoter sequence from nucleotide 21 to 1852 and terminator sequence from 2395 to 3501 (as described in Figure 1). This insert was cloned into pBluescript and the resulting vector is called pSC54

Construct pSC60: The β -glucuronidase reporter coding sequence from vector GUSN358>S (Clontech Laboratories) was placed between the promoter sequence from nucleotide 1 to 2023 and terminator sequence from 2867 to 3925 (as described in Figure 2). This insert was cloned into pBluescript and the resulting vector is called pSC60.

pSC54, pSC60 and a promoter-less GUS construct (Control) were introduced into the flax embryos using particle bombardment using standard protocols (eg see Abenes *et al.* (1997) Plant Cell reports 17:1-7). Figure 8 shows the GUS activity of flax embryos bombarded with pSC54, pSC60 and a promoterless GUS construct measured 48 hours after particle bombardment. As can be seen the flax oleosin regulatory sequences are sufficient to drive the expression of GUS in flax embryos.

EXAMPLE 5

Stable seed specific expression of β -glucuronidase (GUS) in flax and Arabidopsis when under the regulatory control of flax 2S storage protein gene promoter

A GUS reporter gene construct was made by incorporating 5' and 3' regions from the DNA fragment described in Figure 3 into promoterless-GUS pBI101 vector as follows.

A 400bp amplicon from the 5' end of the DNA fragment described in Figure 3 was PCR amplified using the following primers (location shown in Fig 3):

5' primer(1): 5'-TCCAATATGTAGGTCATA-3' (SEQ.ID.NO.:14)

3' primer(1): 5'-CTTTAAGGTGTGAGAGTC-3' (SEQ.ID.NO.:15)

The PCR primers also contained restriction sites for HindIII and BamHI which were used to clone the 400bp 5'UTR amplicon into the HindIII/BamHI sites of the pBI101 vector in front of the GUS reporter gene. A 736bp amplicon from the 3' untranslated region (3'UTR) of the DNA fragment described in Figure 3 was PCR amplified using the following primers (location shown in Fig 3):

5' primer (2): 5'-AGGGGTGATCGATTA-3' (SEQ.ID.NO.:16)

3' primer (2): 5'-GATAGAACCCACACGAGC-3' (SEQ.ID.NO.:17)

The PCR primers also contained restriction sites for *SacI* and *EcoRI*. The NOS terminator region of the pBI101 vector was cut out with *SacI*/*EcoRI* digestion and replaced with the similarly digested 736bp 3'UTR amplicon of the DNA fragment described in Figure 3.

5 The GUS reporter construct was then electroporated into *Agrobacterium tumifaciens* strain AGL1 and transformation of flax (Finnegan *et al.* (1993) Plant Mol Biol. 22(4): 625-633) and *Arabidopsis* (Valvekens *et al.* Proc. Natl. Acad. Sci. 85: 5536-5540) carried out according to previously described protocols.

10 Various tissues from flax and *Arabidopsis* plants carrying the GUS reporter construct were assayed histologically for evidence of GUS activity. In the case of flax, leaf tissue, root tissue and mid-maturity embryos dissected out of developing seeds were stained for GUS activity. For *Arabidopsis*, developing seeds were stained for GUS *in situ* in their siliques.

15 GUS staining was carried out by immersing the tissues in histochemical buffer containing 0.5 mM X-gluc, 0.5 M potassium phosphate buffer (pH 7.0), 1 mM EDTA, 0.5 M sorbital, 0.5 mM potassium ferricyanide and 0.5 mM potassium ferrocyanide. The staining reaction was carried out for 12-16 hrs at 37°C and the reaction was stopped by adding 95% ethanol. Tissues were subsequently cleared of chlorophyll by repeated washing in 95% ethanol prior to photography. Figure 9 shows clear evidence of strong GUS activity in 20 developing flax embryos and *Arabidopsis* seeds, and no evidence of GUS reporter gene expression in flax roots or leaves, or in *Arabidopsis* silique walls.

EXAMPLE 6

25 Stable seed specific expression of β -glucuronidase (GUS) in flax, *Arabidopsis* and *Brassica napus* when under the regulatory control of flax legumin-like storage protein gene regulatory sequences

30 A construct was made using standard molecular biology techniques, including restriction enzyme digestions, ligation and polymerase chain reaction (PCR). In order to obtain a DNA fragment containing approximately 2 kilobases from the 5' transcriptional initiation region of the flax legumin-like seed storage protein in a configuration suitable for ligation to a GUS coding sequence, a PCR based approach was used. This involved the use of the polymerase chain reaction to amplify the precise sequence desired for the expression analysis. To perform the necessary PCR amplification, two oligonucleotide primers were synthesized (Beckman Oligo 1000M DNA synthesizer) have the following sequences:

5' primer: 5'**TA**TA**CTAGACTCAAGCATACGGACAAGGGT** 3' (SJ-634) (SEQ.ID.NO.:18)

35 The italicized bases correspond to nucleotide positions 1 to 21 in the sequence reported in Figure 4. The additional nucleotides 5' of this sequence in the primer are not identical to the promoter sequence, but were included in order to place a *XbaI* site at the 5'

end of the amplification product. The XbaI (5'-TCTAGA-3') (SEQ.ID.NO.:19) site is underlined.

A second (3') primer was synthesized which had the following sequence:

3' primer 5'GGTTATCATTGTATGAACTGA3' (SJ-618) (SEQ.ID.NO.:20)

5 This primer contains the precise complement (shown in italics) to the sequence reported in Figure 4 from bases 2343 to 2363. This primer was not designed with an additional restriction enzyme site due to the fact that a natural NcoI site (5'-CCATGG-3') (SEQ.ID.NO.:21) straddles the start codon between base pairs 2034 and 2039, thereby allowing for insertion of the storage protein promoter into the appropriate cloning vector.

10 These two primers were used in a PCR amplification reaction to produce a DNA fragment containing the sequence between nucleotides 1 and 2342 of the flax seed storage protein gene with a XbaI site at the 5' end and a NcoI site 302 base pairs from the 3' end. PCR amplification was performed using the enzyme Pfu (Stratagene) using conditions recommended by the enzyme manufacturer and a temperature program of 94°C
15 (denaturation) for 1 minute, 55°C (annealing) for 1 minute, and 72°C (elongation) for 3.5 minutes. The template was the legumin seed storage protein genomic clone shown in Figure 4.

The resulting amplification product was subsequently digested with XbaI and NcoI to remove the desired 2 kb promoter region. This promoter fragment was cloned into
20 the XbaI and NcoI sites of a XbaI and NcoI digested plasmid designated pGUS1318 (Plasmid pGUSN358S (Clontech Laboratories) was cut with NcoI and EcoRI and the GUS insert was cloned into pBluescriptKS+ (Stratagene) which was adapted to contain an NcoI site in the multiple cloning site.) The resulting plasmid containing the promoter-GUS fusion was called pPGUS1318. The terminator of the legumin seed storage protein from flax
25 was also amplified from the above mentioned genomic clone. To perform the necessary PCR amplification, oligonucleotide primers were synthesized having the following sequences:

5' primer: 5' GCAAGCTTAATGTGACGGTGAAATAATAACGG 3' (SJ620) (SEQ.ID.NO.:22)

The italicized bases correspond to nucleotide positions 3780 to 3803 in the sequence reported in Figure 4. The additional nucleotides 5' of this sequence in the primer are not
30 identical to the promoter sequence, but were included in order to place a HindIII site at the 5' end of the amplification product. The HindIII site (5'-AAGCTT-3') (SEQ.ID.NO.:23) is underlined.

A second (3') primer was synthesized which had the following sequence:

3' primer 5'TAGGTACCTGGCAGGTAAAGACTCTGCTC3' (SJ-618) (SEQ.ID.NO.:24)

35 This primer contains the precise complement (shown in italics) to the sequence reported in Figure 4 from bases 4311 to 4290. The additional nucleotides 5' of this sequence in the primer are not identical to the promoter sequence, but were included in order to place a

KpnI site at the 5' end of the amplification product. The KpnI site (5'-GGTACC-3') (SEQ.ID.NO.:25) is underlined.

These two primers were used in a PCR amplification reaction to produce a DNA fragment containing the sequence between nucleotides 3779 and 4311 of the flax seed storage protein gene terminator with a HindIII site at the 5' end and a KpnI site at 3' end. Amplification using PCT was as described above. The above pPGUS1318 vector that contains the amplified promoter was digested with XhoI and treated with Klenow to create a blunt end. The vector was subsequently digested with KpnI and the above amplified terminator sequence was inserted so that it was located 3' of the GUS coding sequence. The resulting vector containing the flax seed storage protein promoter, GUS and the flax seed storage protein terminator is referred to as pPGUST.

The XbaI-KpnI insert of pPGUST which contains the linin promoter-GUS coding sequence-linin terminator sequence was ligated into the XbaI-KpnI sites of pSBS3000 (This vector is a derivative from the *Agrobacterium* binary plasmid pPZP221 (Hajdukiewicz et al., 1994, Plant Molec. Biol. 25: 989-994). In pSBS3000 the plant gentamycin resistance gene of pPZP221 was replaced with parsley ubiquitin promoter-phosphinothricin acetyl transferase gene-parsley ubiquitin termination sequence to confer resistance to the herbicide glufosinate ammonium). The resulting vector is called pSBS2089. In addition the XbaI-KpnI insert of pPGUST which contains the linin promoter-GUS coding sequence-linin terminator sequence was ligated into the XbaI-KpnI sites of the *Agrobacterium* binary plasmid pCGN1559 (MacBride and Summerfield, 1990, Plant Molec. Biol. 14 269-276, confers resistance to the antibiotic kanamycin)). The resulting vector was called pSBS2083. Plasmids pSBS2089 and pSBS2083 were electroporated into *Agrobacterium* strain EHA101. *Agrobacterium* strain EHA101 (pSBS2089) was used to transform flax and Arabidopsis, *Agrobacterium* strain EHA101 (pSBS2083) was used to transform *Brassica napus*. Flax transformation was performed essentially as described in Jordan and McHuguen (1988) Plant cell reports 7: 281-284, except transgenic shoots were selected on 10 µM L-phosphinothricine instead of kanamycin. Arabidopsis transformation was done essentially as described in "Arabidopsis Protocols; Methods in Molecular Biology" Vol 82. Edited by Martinez-Zapater JM and Salinas J. ISBN 0-89603-391-0 pg 259-266 (1998) except the putative transgenic plants were selected on agarose plates containing 80µM L-phosphinothricine. *Brassica napus* transformation was done essentially as described in Moloney et al. (1989). Plant Cell Reports. 8: 238-242.

Figure 10 shows the tissue-specific expression of GUS in transgenic flax plants transformed with a linin-GUS gene construct (pSBS2089). GUS expression was measured in roots (R), stems (S), leaves (L), Buds (B) and embryo (E). Some expression was seen in buds, and maximal expression was achieved in embryo tissues. No detectable expression was seen in any of the untransformed (WT) tissues.

Figure 11 shows the temporal expression of GUS in transgenic flax plants transformed with a linin-GUS gene construct (pSBS2089). As can be seen, maximum expression is achieved in mature (pre-dessicated) flax embryos.

5 Figure 12 shows the absolute expression of GUS in transgenic *Brassica napus* plants (L1 to L9) transformed with a linin-GUS gene construct (pSBS2083). As can be seen high level expression can be achieved in *Brassica napus* plants. When comparing individual transgenic plants, a typical variation in expression due to position effect can also be seen.

10 Figure 13 shows expression of GUS in transgenic *Arabidopsis* siliques (transformed with a linin-GUS gene construct (pSBS2089)) during seed development. As can be seen high level expression can also be achieved in *Arabidopsis* seed tissues. Maximum expression is achieved at stage 4 (mature but not fully dessicated) of seed development. No detectable expression is observed in non-seed tissues such as leaves, stems, roots and silique walls (results not shown).

15 While the present invention has been described with reference to what are presently considered to be the preferred examples, it is to be understood that the invention is not limited to the disclosed examples. To the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

20 All publications, patents and patent applications are herein incorporated by reference in their entirety to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety.

We Claim:

1. A method for the expression of a nucleic acid sequence of interest in flax seeds comprising:
 - (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3' direction of transcription as operably linked components:
 - (1) a seed-specific promoter obtained from flax; and
 - (2) said nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
 - (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
 - (c) growing said flax plant cell into a mature flax plant capable of setting seed wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.
2. The method according to claim 1 wherein at least one expression characteristic conferred by said seed-specific promoter to its native nucleic acid sequence is conferred to said non-native nucleic acid sequence.
3. The method according to claim 2 wherein said expression characteristic is timing of expression, level of expression, response to a change in lighting conditions, response to a change in temperature, response to a change in concentration of a chemical agent.
4. The method according to claim 1 wherein said flax seed-specific promoter is selected from the group of promoters comprising, oleosin promoters, 2S storage protein promoters and legumin-like seed-storage protein promoters.
5. The method according to claim 1 wherein said flax seed-specific promoter comprises:
 - (a) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be U;
 - (b) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (a);
 - (c) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a) or (b);
 - (d) a nucleic acid sequence that is an analog of a nucleic acid sequence of (a), (b) or (c); or
 - (e) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a), (b), (c) or (d) under stringent hybridization conditions.

6. The method according to claim 1 wherein expression of said nucleic acid sequence of interest results in an alteration in protein or fatty acid composition in said seed.
7. Transgenic flax seed prepared according to a method comprising:
- 5 (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3' direction of transcription as operably linked components:
- (1) a seed-specific promoter obtained from flax; and
- (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
- 10 (c) growing said flax plant cell into a mature flax plant capable of setting seed wherein said nucleic acid sequence of interest is expressed in the seed under the control of said seed-specific promoter.
8. Transgenic flax seed according to claim 7 wherein at least one expression characteristic conferred by said seed-specific promoter to its native nucleic acid sequence is
- 15 conferred to said non-native nucleic acid sequence.
9. The method according to claim 8 wherein said expression characteristic is timing of expression or level of expression.
10. Transgenic flax seed according to claim 8 wherein said seed-specific promoter is a seed storage protein promoter, an oleosin promoter, a 2S storage protein promoter or a
- 20 legumin-like seed-storage protein promoter.
11. Transgenic flax seed according to claim 8 wherein said seed specific promoter comprises:
- (a) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8)
- 25 wherein T can also be U;
- (b) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (a);
- (c) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a) or (b);
- 30 (d) a nucleic acid sequence that is an analog of a nucleic acid sequence of (a), (b) or (c); or

- (e) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a), (b), (c) or (d) under stringent hybridization conditions.
12. Transgenic flax seed according to claim 8 wherein expression of said non-native gene of interest results in an alteration in the seed protein or fatty acid composition.
- 5 13. Transgenic flax plants capable of setting seed prepared by a method comprising:
- (a) preparing a chimeric nucleic acid construct comprising in the 5' to 3' direction of transcription as operably linked components:
- 10 (1) a seed-specific promoter obtained from flax; and
- (2) a nucleic acid sequence of interest wherein said nucleic acid of interest is non-native to said seed-specific promoter;
- (b) introducing said chimeric nucleic acid construct into a flax plant cell; and
- (c) growing said flax plant cell into a mature flax plant capable of setting seed wherein said nucleic acid sequence of interest is expressed in the seed under the control of
- 15 said seed-specific promoter.
14. An isolated nucleic acid sequence capable of directing seed-specific expression in a plant comprising:
- (a) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be U;
- 20 (b) a nucleic acid sequence that is complementary to a nucleic acid sequence of (a);
- (c) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a) or (b); or
- 25 (d) a nucleic acid sequence that is an analog of a nucleic acid sequence of (a), (b) or (c); or
- (e) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a), (b), (c) or (d) under stringent hybridization conditions.
15. An isolated chimeric nucleic acid sequence comprising:
- 30 (a) a first nucleic acid sequence comprising a seed-specific promoter obtained from flax which comprises:
- (1) a nucleic acid sequence as shown in Figure 1 (SEQ.ID.NO.:1), Figure 2 (SEQ.ID.NO.:4), Figure 3 (SEQ.ID.NO.:6) or Figure 4 (SEQ.ID.NO.:8) wherein T can also be U;

- (2) a nucleic acid sequence that hybridizes to a nucleic acid sequence of (a) under stringent hybridization conditions;
- (3) a nucleic acid sequence that is complimentary to a nucleic acid sequence of (a); or
- 5 (4) a nucleic acid sequence that has substantial sequence homology to a nucleic acid sequence of (a); and
- (b) a second nucleic acid sequence non-native to said flax seed-specific promoter.

16. A method for the expression of a nucleic acid sequence of interest in a plant seed comprising:

- (a) introducing the chimeric nucleic acid sequence according to claim 15 into a plant cell; and
- (b) growing said plant cell into a mature plant capable of setting seed,
- wherein the second nucleic acid sequence is expressed in the seed under the control of the
- 15 seed specific promoter.

17. A method according to claim 16 wherein said plant cell is selected from the group of plants consisting of soybean (*Glycine max*), rapeseed (*Brassica napus*, *Brassica campestris*), sunflower (*Helianthus annuus*), cotton (*Gossypium hirsutum*), corn (*Zea mays*), tobacco (*Nicotiana tabacum*), alfalfa (*Medicago sativa*), wheat (*Triticum sp.*), barley

20 (*Hordeum vulgare*), oats (*Avena sativa* L.), sorghum (*Sorghum bicolor*), *Arabidopsis thaliana*, potato (*Solanum sp.*), flax/linseed (*Linum usitatissimum*), safflower (*Carthamus tinctorius*), oil palm (*Eleais guineensis*), groundnut (*Arachis hypogaea*), Brazil nut (*Bertholletia excelsa*) coconut (*Cocus nucifera*), castor (*Ricinus communis*), coriander (*Coriandrum sativum*), squash (*Cucurbita maxima*), jojoba (*Simmondsia chinensis*) and rice

25 (*Oryza sativa*).

18. A plant prepared according to the method of claim 16.

19. A plant cell comprising the chimeric nucleic acid sequence according to claim 15.

20. Plant seed comprising the chimeric nucleic acid sequence according to claim 15.

21. Plant seed obtained from a plant prepared according to the method of claim 16.

30 22. A recombinant expression vector comprising a nucleic acid sequence according to claim 14.

23. A recombinant expression vector comprising a nucleic acid sequence according to claim 15.

FIGURE 1-1

1 ttcaaaacccgattcccagagggccctattgaagatatgggggaagtctcgacgagatcgatgtcgggtcgagtgtctatg 80
 81 gtgatggtgccgttttggggggaggatgagcgagatagccaagactagcattccgttccccacacagagttgggaatttcta 160
 161 ccaaatccaacacttgcgtattgagcgacgtagggacgcggaaaaacacatccgttggatcagggagttgtacgatg 240
 241 atctcgagccttatgtgtcgaagaatccgagggtatgcttacgtgaactacagggatctcgacatcgggatgaatggagga 320
 321 ggtgaaggggatgagaagggtacttatggtgaggctaaaggtgtgggggagaagtactttgggggtcaactttgatcgggtt 400
 401 ggttcgggtgaagacgattgttgatcccaataatgtgtttcgaaacgagcagagcattccctcaattccaactcgggttat 480
 481 aaggatcaatgatcaatgagaattttcctttccaatgtgattacaaagtctattgggtcagcttttctcaactgtctcctat 560
 561 tcatttttagatttaataacaactattaattaccagccttttatccggccgttgccgatttatatttcttaagtttt 640
 641 agatgaaatgaaaccgatttagtttttattgagatgagattaaatcttaattttgcttgaaatttactcacggttgatgtga 720
 721 tatttggaaattaactaaaatgataaaatcggtataaaaaataaaatattt^{R3}taaaataaaataaaacataaagaacaata 800
 801 aaataaaataaaattt^{I1}aaattt^{R4}attt^{R4}cttctgtatcatcatcttcttcttacttctttaaaggctt 880
 881 ttcaattatcaccttaataataacataagataaaatcggttaattctataacattaaacctatacacattgacggtgaacaat 960
 961 caatatgataataataataataataattcaattattaatctacaatttttaattataaaagtttatgcggtcagtt 1040
 1041 tctgcaagctccgagctccttgtcatcgtttagtttctgcggtctcaaggtataacgactcggagcagagccctttgct 1120
 1121 tccaatggacgggttgcatcttctgccgtcgttgagctcgattggcgtgtcatgctggagtcagagttcctacaaaaaac 1200
 1201 cctaaactagaggggtgattaggggtgaaattaggggttgccctgggttccattgtccaaagttttagtcaacttaaaaaac 1280
 1281 agacttaaaattttatgcttcaaaaatagttttatctgtttattatattagcgtgtaattagctcttgacaatggggccggacgg 1360

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FIGURE 1-2

1361 gtacggattcgggaccccgatccccgcccatagtgtaatggctcaactgccaagtcagcattggaccgaaattattggac 1440
 1441 acgaagtactaatgtgaaaaaacttttacatttgttattttctactttaatactatgctattttcaaaaatttgaactttaat 1520
 1521 actatgtttttatagtttagtataatcttaatttttatgcaaaattcatctaaattgtattataaactatttttcgatccgtag 1600
 1601 ctaattatttcgaaggcaagtc aaagtgttattgtggactatgtgagctaatttgaaacctttatctctcccaaccactc 1680
 1681 aagttaattgaacaaactcgatcggttggttcgagctatttcgagccattgtgttatatgcacgtgagatatcaag 1760
 1761 attgacccgaacactttattatgataatgtagaaaaaagaaaaacataatttctaagactacatgcatgcaaaagtgc aacccct 1840
 1841 gcatggaaagctgctcaaacacggtggcatagactcccgccacggtgtccattccacctcatcacctcaccaccccgttcac 1920
 1921 ctcttattatcacacaatcaatcaatcctactcctcctactcctcctactcgaacaaatccgaccaacttataccaatattccca 2000
 2001 aacttgattaaatttctcagcaat ATG GAT CAG ACG CAC CAG ACA TAC GCC GGA ACC ACG CAG AAC 2065
 1 M D Q T H Q T Y A G T T Q N 14
 2066 CCG AGC TAT GGC GGC GGC ACA ATG TAC CAG CAG CAG CCG AGG TCT TAC CAG GCG 2125
 15 P S Y G G G T M Y Q Q Q Q P R S Y Q A 34
 2126 GTG AAG GCG GCC ACT GCA GCC ACC GCG GGT GGA TCC CTC ATC GTT CTG TCC GGT CTC ATC 2185
 35 V K A A T A A T A G G S L I V L S G L I 54
 2186 CTT ACG GCC ACC GTC ATT TCA CTC ATC ATA GCC ACC CCT CTC CTC L L V I F S P 2245
 55 L T A T V I S L I I A T P L L V I F S P 74
 2246 GTT CTT GTC CCG GCT CTC ATC ACC GTC GGC CTC TTG ATC ACC GGG TTT CTT GCT TCC GGT 2305
 75 V L V P A L I T V G L L I T G F L A S G 94
 2306 GGG TTC GGA GTC GCC GGC ACC GTC TTG TCC TGG ATC TAT AG gtatgtataagcctttggactt 2370
 95 G F G V A A V T V L S W I Y R 109
 2371 tagtattgttataaaataacataaagctgatttatgaacatggatctctcccaacaagagtattttaaatgcatctcgtctg 2450

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FIGURE 1-3

2451 actcgatcgggttgggttttgagctactcgggtcacaaatggtcgggtcggtcttgatctgttatactaataatttgaagcc 2530
 2531 tgaagtttcattgttctgcccccaacttcccactaccttttgagggtgtttaagaagccatacaaaactaattatgaatccct 2610
 2611 cccaacaactcagaactcgagtcagtggtgtgtgacggttctctataaacaatttcgaaaaatcttgttcaatgaacgtag 2690
 2691 aaatgaccatgcttgatgattgtgggtcttataag G TAC GTG ACC GGC GGG CAC CCG GCG GGA GGG 2756
 110 Y V T G G H P A G G 119
 2757 GAT TCG CTG GAC CAG GCT AGG TCG AAG CTG GCC GGA AAG GCC AGG GAG GTG AAG GAC AGG 2816
 120 D S L D Q A R S K L A G K A R E V K D R 139
 2817 GCG TCG GAG TTC GCA CAG CAG CAT GTC ACA GGT GGT CAA CAG ACC TCT TAA agagagtcctct 2879
 140 A S E F A Q Q H V T G G Q Q T S * 156
 2880 agttaaatgttcttctgtttctgttctgtggggtgtgtaaaactctcttttaagtgtgctgttttcttctcgtgt 2959
 2960 gttgtaagtgaagtgtaatacgaagttccaagtttgagatgtttgttaacgatgtgttttctaataatcagagatattaa 3039
 3040 aagggttgctaatttagtattgctgtctgatctcggaccacaaactcgcaagtaaaattgcagaggatgagttgtacagaaca 3119
 Poly A signal
 3120 agcgtgcattgttctggaagttcatctccttggagccgaccttgttgcagtttccgccaagtcactagacaaatgtt 3199
 3200 acgagttaagcctctgtcaaacagatcgctctagcggtccagaaaaacaccagatttttgcgaaaaccatcggggatcaatt 3279
 3280 ttcgattcaattccgatcttgggaagtacttgaacagaagcatgatgctaaaaagataataagaaaatcgaaagcctagaaaaag 3359
 3360 ttgtacagaaagcaacaagtcaaaaaatatagatcaacttcaaaggttcaaattacatcttacagacccccaaaaatgaca 3439
 3440 gttaacagaagtcgactaaacagaaaccagccagcttcacctgggaatgaaggagctttgatcaatccatccttagcttcat 3519
 3520 tccccctttgaaattgcagacagagctctcatcctgctaaaagctgtggtgttattcttaacccctgcaatcaataagcatga 3599
 3600 actaacattggacaccttcatcggcggttgcgtcgaaaaatcagtgagcgagggttaccctgtgtgtgtagtaaacctctc 3679

FIGURE 1-4

3680 tccttgataaaaatctgaaattccggcatcaactactgccacctttctgcttaaggtgattttatcaccaaggctga 3759
3760 gcgtgattccttgcgctcttgctccgaatcctgatgtatccactgagctttccatctccttctccttctccaggccttatgttc 3839
3840 accaatgcgtcctcgccgaacacactcttggcgtaaaagtgcagccaggaatccacactctccatcaagtgcagacct 3919
3920 gcaaaccccaataaagaacacaaaactccaaagtcaacgatcaattctccgccttttatgaagaaaaaggaaacttctgggt 3999
4000 acttacggtgccgtcagacacttccatattttagacttgatgatatggtccaggaaattccttctcgttctgaattgtgt 4079
4080 gttaacagcaaacctgacagacagaaagatatcgcaaaatttaagatactgggatgactaggcacagagaaaaatgaaatcttaa 4159
4160 ttctagaagtaaaaccttattttcccatcattcctgcccacatagtcgggaacgcagcatccgaggaagaagcaggag 4239
4240 agatgtaatccatgatgcgatgtggatatcggttgaggacgacaactgaacgttcccatcacattgg 4305

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FIGURE 2-1

1 tctagacatttgacataaaacggaattcaaaagaacacaacattgactaaacacacaaagaaatagagtagtgaaaatttggg^{R1} 80
 81 agattaaaaaatagaacaaaactgattcttagaaagaagagatgattaggtgcttttcagttcggctctgtcaggaaaatcga^{R2} 160
 161 gatgttcacttatttacattgtcgaattcattcctccaaatgtcctggttccttactgtccgacgcttttttgaatcccag 240
 241 ttaattcccatcaaagtcttcttcagctgcgtagcactgctagctccaacatggagcgtgagctctactcgttcattggtggg 320
 321 catcgcaaagggttgccttcatgttctgctaccagccagccacccgctcttgggtgtgtggacaaattgcggtgaagc 400
 401 gcgcaagttgacatcccatagttctcgacacttcaccatatggatgttttaaaacgtatatcacgagtgcgatctacatgtc 480
 481 ccatcacaccacataataaagcaatagtttgggagcttttcatatttgaaacgggcattgacgacttgcctctcgcataat 560
 561 ttaatctttttctcttcagctgattgtgtgcatccattcgggctcagaagcacatcaaaaggatctctccatcgtagt 640
 641 attgggtcgtgtatgatacgaagcagtcgatgaagtctcctaattgtcgagctacaggctccgaaagaaacccgcga 720
 721 ggtagatcgtatgtagtaccacaaaatcagtttgtcgtagcgggaatcaacactagagactcacccctaataatgcatctcatg 800
 801 tgtgatgaacagtttatcatttgtgagtctaggggtcattgtcgaatgaccccaatgcacattgagcttatgatagaaattg^{R3} 880
 881 aataggaagcgttttccaccagatcacgaatagctaccccttttttcgggcgccaaatttccggcatcctatcttccacc 960
 961 acaacttaagatgcgatcggtaaggaaactcacccgaccacacacatcgaataatcttcggtgaccgggttcctgttgatca 1040
 1041 agtccctcaatttccctcaacctagtcttcaatcgccgtagcgttatcccccgcatatggactttcatagcgggagcgt 1120
 1121 agccggagacgacgagcaagaaggatgagcggcgagattgcgggtaaaagaaacgagcttccctgctctatggag 1200
 1201 gcagatttctgagttgattggtgattgtgtgtaggacacttttaattaaagtgtatttttagcacttccattcacg 1280
 1281 taattaaataaataattccagtatatttatatttatttcccttacgttatctaatatttttgaagagattaaaaactttgtatat^{R2} 1360
^{R4}

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FIGURE 2-2

1361 aggcaagatcatgacacgctcgaagttaagtgaatgagactccttaacaaggtaataaacaagcagttcataaaaccggaatga 1440
 1441 ccttgatctttactaagcttgagatcattgaacatataaattaaatacgtttaatgaaagataagaactttaataataaaat 1520
 1521 cattcaaaacgagaaactgataaacaacaaacgcaaacgcaaaataataagacggtggaaggatgatgcagagcc 1600
 1601 atccaccctttttccagtttcccttactgcttacttctctatgcataatcacaaagcgccttgaaacttggtagtcag 1680
 1681 cagagcccttactcgccaggtcaccgcaccacggtgttactctatcacttctcctccttcccttaaaagaaccaccacgc 1760
 1761 cacctccctctcacaacactcataaaaaaacccacctcttgcatcttcccaagttcaaaattagttcacagtaagcaag 1840
 1841 aactcaacaaca ATG GCG GAT CGT ACA ACA CAG CCA CAC CAA GTC CAG GTC CAC ACC CAG CAC 1903
 1 M A D R T T Q P H Q V Q V Q V H T Q H 17
 1904 CAC TAT CCC ACC GGC GGT TTC GGC CGT TAT GAA GGT GGA CTC AAA GGC GGT CCA CAT 1963
 18 H Y P T G G A F G R Y E G G L K G G P H 37
 1964 CAC CAG CAA GGA TCA GGC AGC GGC CCA TCA GCT TCC AAG GTG TTA GCA GTC ATG ACC GCG 2023
 38 H Q Q G S G S G P S A S K V L A V M T A 57
 2024 CTC CCC ATC GGC GGC ACC CTC CTT GCC TTG GCC GGG ATA ACC TTG GCT GGG ACG ATG ATC 2083
 58 L P I G G T L L A L A G I T L A G T M I 77
 2084 GGG CTG GCG ATC ACC ACC CCG ATT TTT GTC ATC TGC AGC CCT GTT CTA GTC CCG GCC GCT 2143
 78 G L A I T T P I F V I C S P V L V P A A 97
 2144 CTG CTC ATC GGG TTT GCC GTG AGC GCG TTT CTG GCC TCG GGG ATG GCC GGT CTA ACA GGG 2203
 98 L I G F A V S A F L A S G M A G L T G 117
 2204 CTG ACC TCG CTG TCG TGG TTT GCG AGG TAT CTG CAG CAG GCT GGG CAG GGA GTT GGA GTG 2263
 118 L T S L S W F A R Y L Q Q A G Q G V G V 137
 2264 GGG GTG CCG GAT AGT TTC GAG CAG GCG AAG AGG CGC ATG CAG GAT GCT GCT GGG TAT ATG 2323
 138 G V P D S F E Q A K R R M Q D A A G Y M 157

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FIGURE 3-1

1 tccactatgttaggtcatatcccatcttttaatttttggccaccattcaattcccatcttgccttttagggatgtgaatatga 80
5' primer (1) AT rich

81 acggccaaggtaagagataaaaaataatcccaattaaagcaagagagggccaagtaagataatcccaatgtacacttgtca 160
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RY G box seed-specific

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641 GCCACAGCCACTATTACAACCAGGGCCGTGGAGGAGCGGAACAGAGCCAGTACTTTCGAACAGCTGTTGTGACGACCTTA 720
76 H S H Y Y N Q G R G G G E Q S Q Y F E Q L F V T T L 101

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801 GGGACAGCAGCAGGACAGCAGGAGTTTCAGAGGTGGATCCAGCAAGCTAAACAAATCGCTAAGGACCTCCCCGGAC 880
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FIGURE 4-1

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FIGURE 4-3

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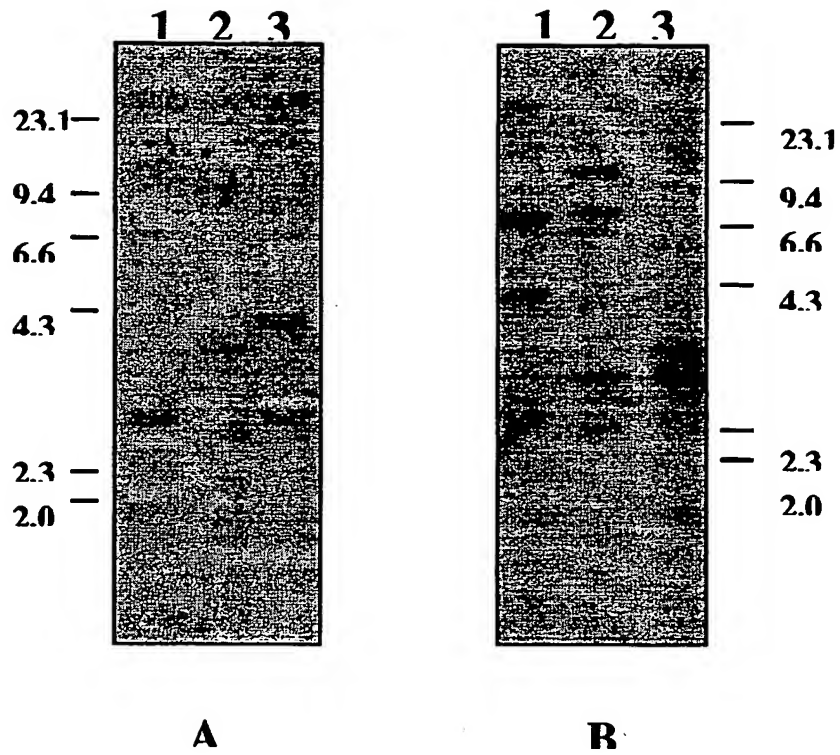
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FIGURE 4-4

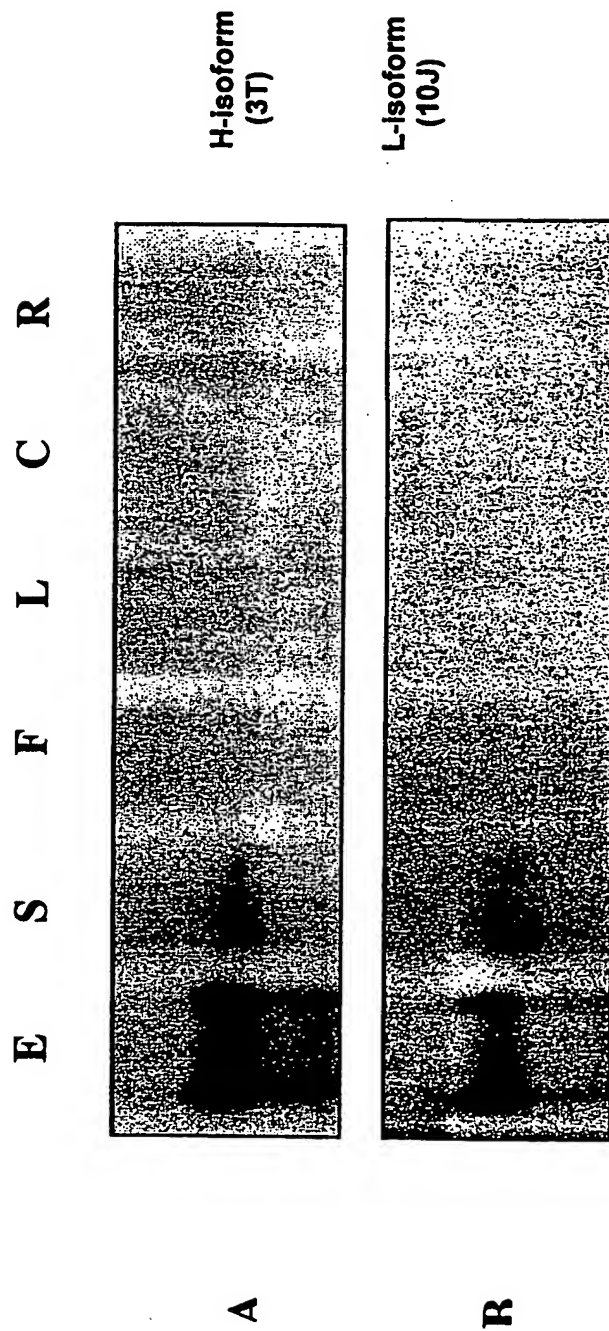
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FIGURE 5



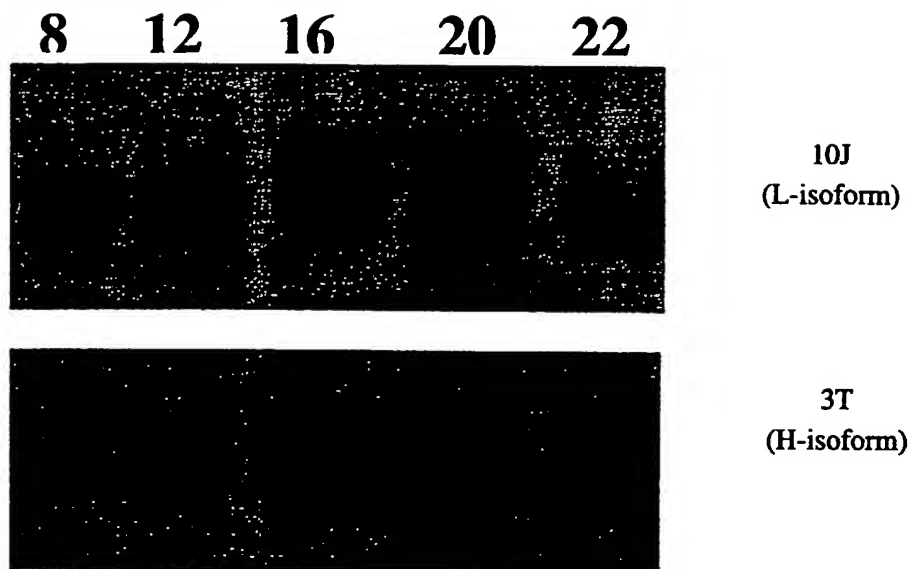
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FIGURE 6

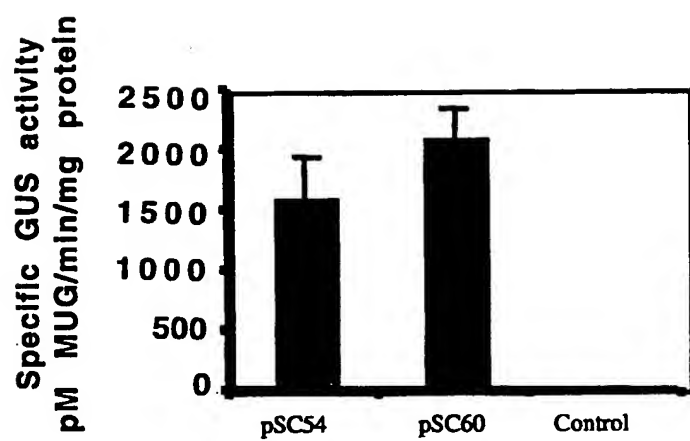


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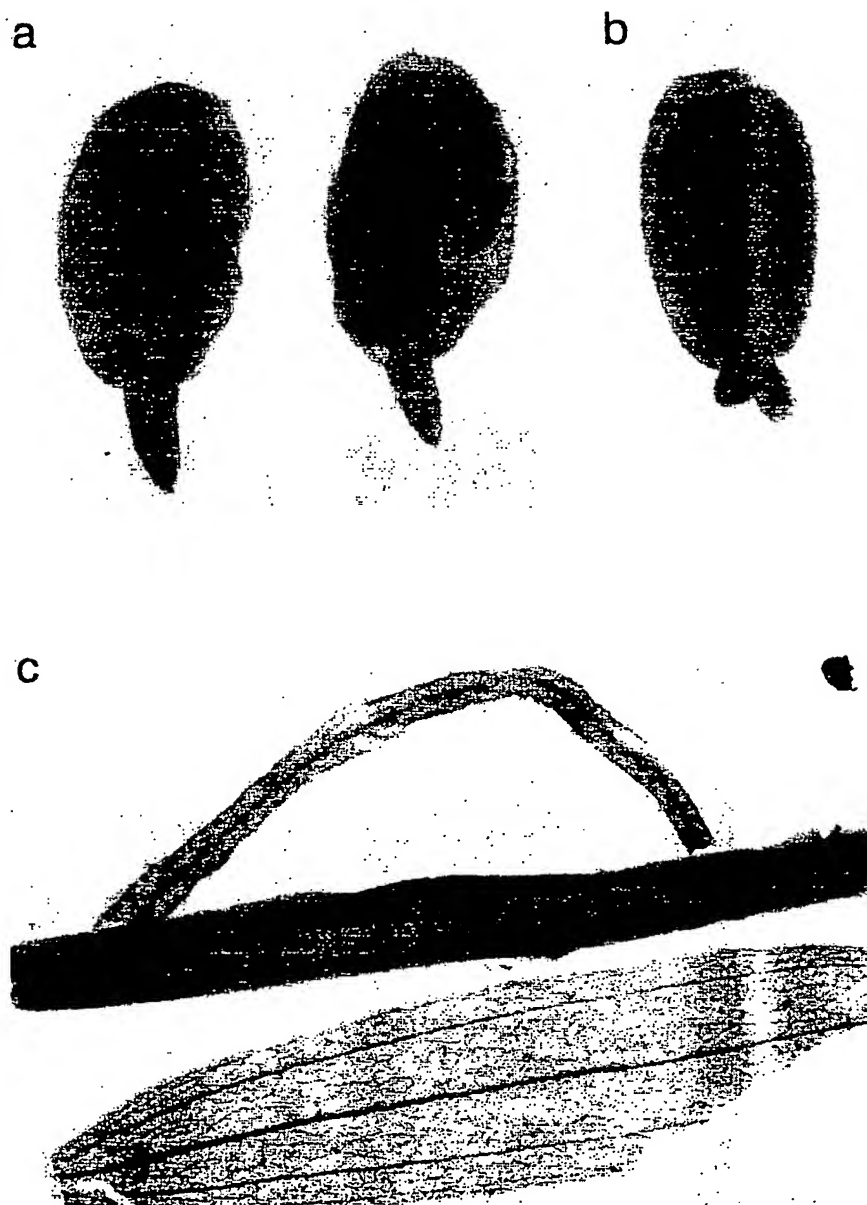
FIGURE 7



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FIGURE 8



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Figure 9.1



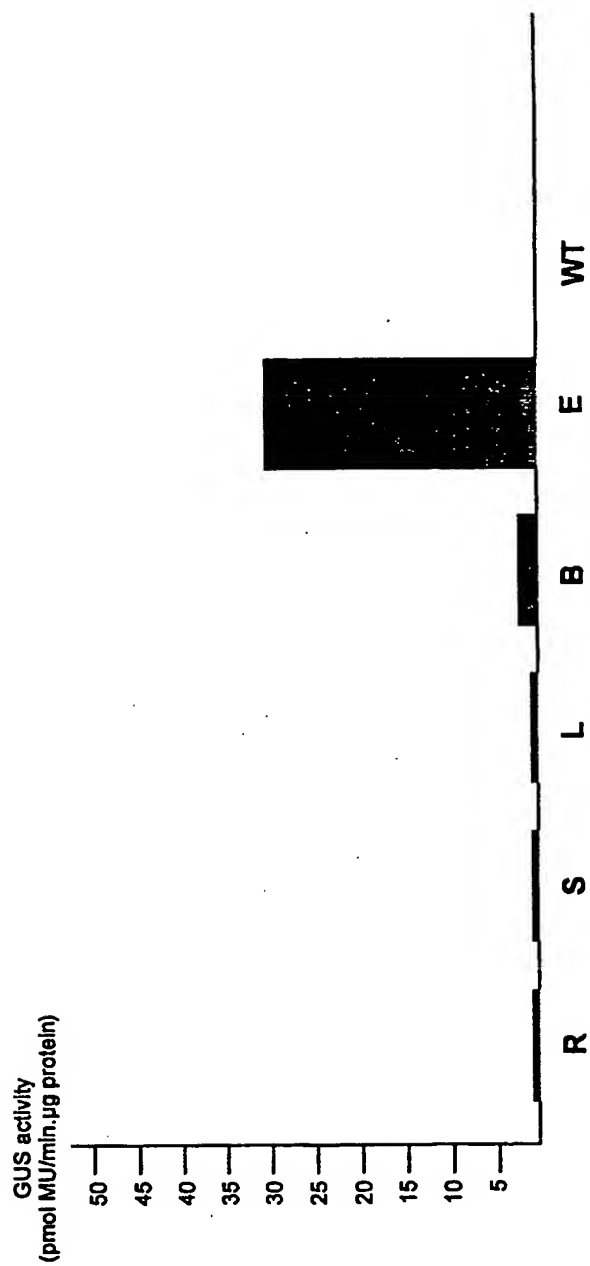
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Figure 9.2



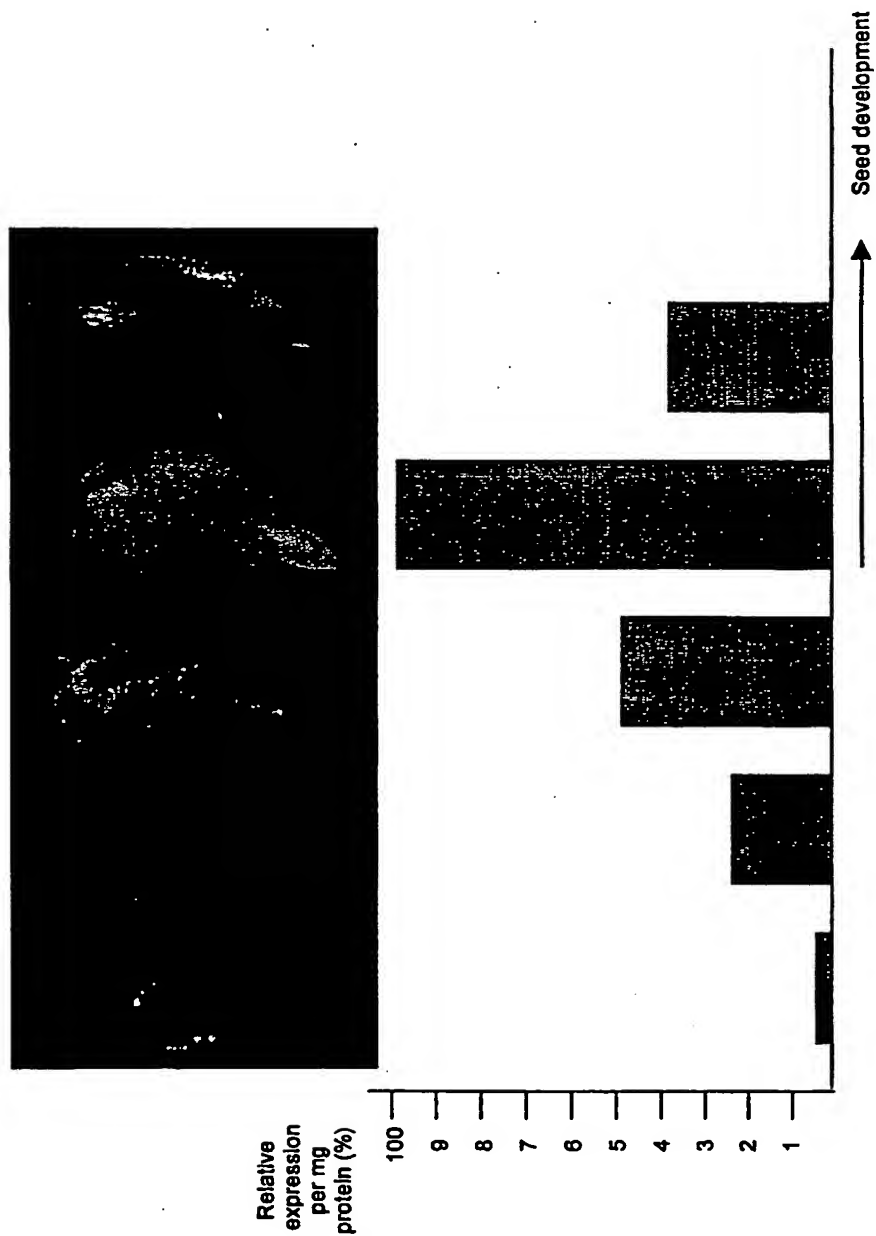
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FIGURE 10



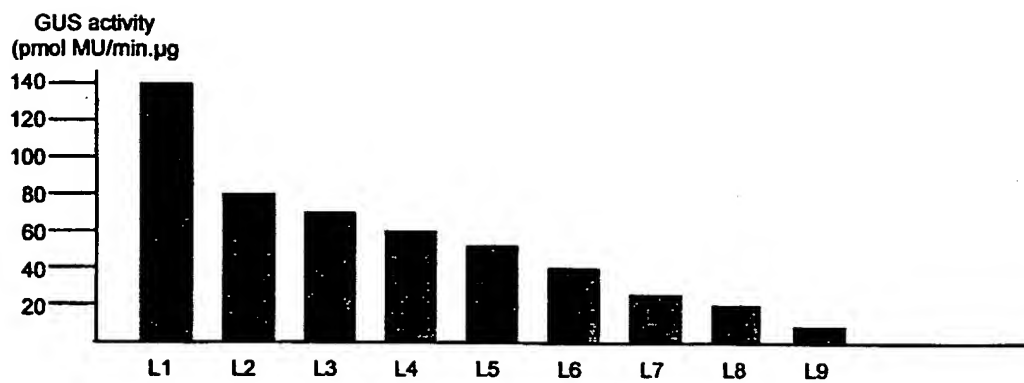
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FIGURE 11



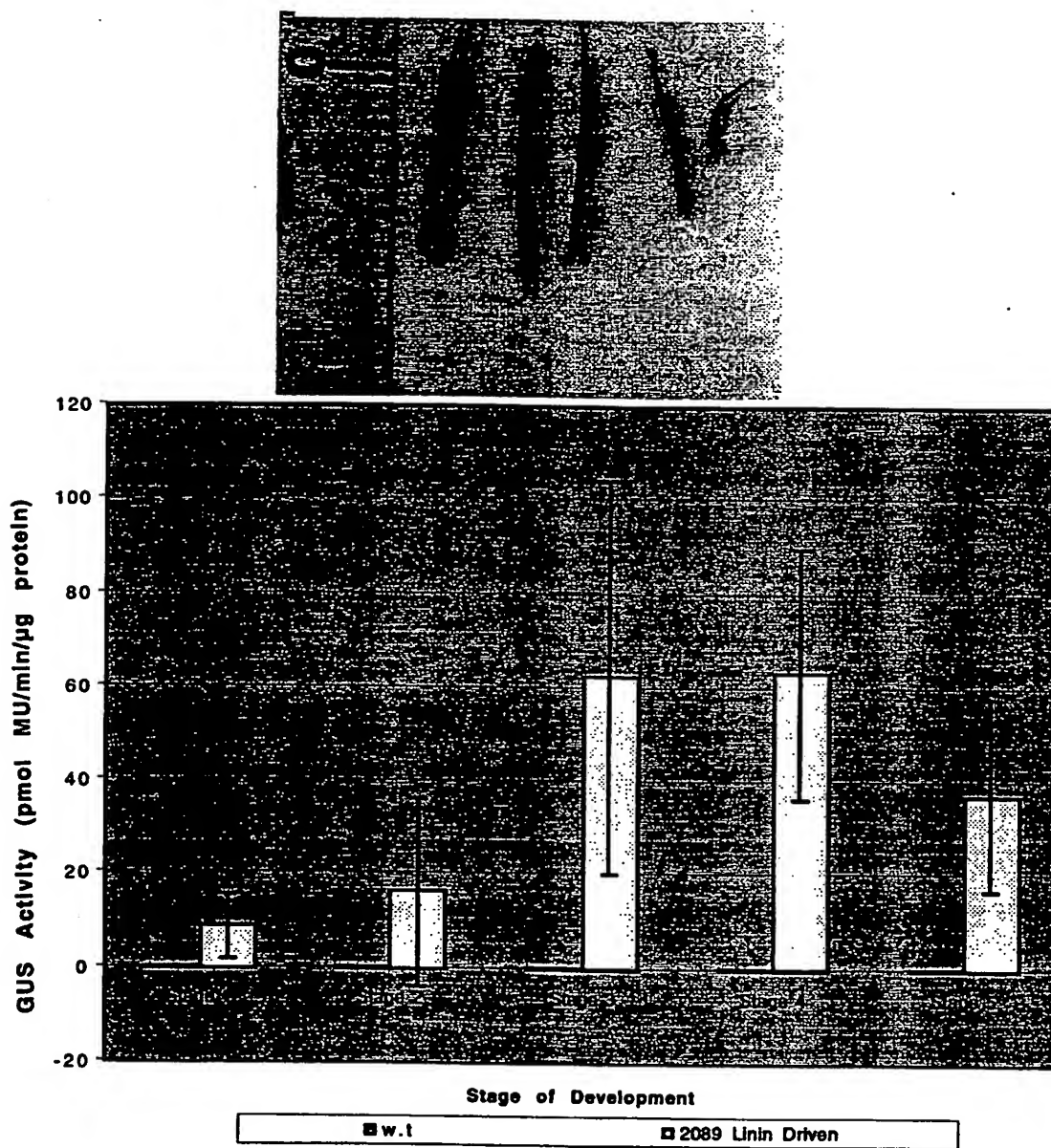
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FIGURE 12



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FIGURE 13



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SEQUENCE LISTING

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      35             40             45

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Ser Lys Val Leu Ala Val Met Thr Ala Leu Pro Ile Gly Gly Thr Leu
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Leu Ala Leu Ala Gly Ile Thr Leu Ala Gly Thr Met Ile Gly Leu Ala
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Ile Thr Thr Pro Ile Phe Val Ile Cys Ser Pro Val Leu Val Pro Ala
      85             90             95

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Ala Gly Leu Thr Gly Leu Thr Ser Leu Ser Trp Phe Ala Arg Tyr Leu
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 Val Cys Glu Gln Gln Ile Gln Gln Arg Asp Phe Leu Arg Ser Cys Gln
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 85 90 95
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130

135

140

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<212> DNA

<213> Linum usitatissimum

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          20             25             30
Glu Cys Gln Ile Asp Arg Ile Asp Ala Ser Glu Pro Asp Lys Thr Ile
          35             40             45
Gln Ala Glu Ala Gly Glu Val Trp Asp Gln Asn Arg Gln Gln Phe Gln
          50             55             60
Cys Ala Gly Val Ala Val Val Arg Arg Thr Ile Glu Pro Lys Gly Leu
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Leu Leu Pro Phe Tyr Ser Asn Thr Pro Gln Leu Ile Tyr Ile Val Gln
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 35 40 45
 Val Pro Ala Gly Val Ala His Trp Ser Tyr Asn Asp Gly Asn Glu Pro
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<212> PRT

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 35 40 45
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 50 55 60
 Leu Gln Ser Glu Asn Asp Asn Arg Gly Gln Ile Val Arg Val Glu Gly
 65 70 75 80
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 Glu Gln Gly Gly Arg Gly Gly Gly Arg Tyr Tyr Ser Asn Gly Val Glu
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 Glu Thr Phe Cys Ser Met Arg Leu Ile Glu Asn Ile Gly Asp Pro Ser
 115 120 125
 Arg Ala Asp Ile Phe Thr Pro Glu Ala Gly Arg Val Arg Ser Leu Asn
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 Gly Val Leu Tyr Asn
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<213> Linum usitatissimum

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 35 40 45
 Pro Gln Asn Phe Ala Val Val Lys Arg Ser Gln Ser Glu Arg Phe Glu
 50 55 60
 Trp Val Ala Phe Lys Thr Asn Asp Asn Ala Met Val Asn Ser Leu Ala
 65 70 75 80
 Gly Arg Thr Ser Ala Val Arg Ala Ile Pro Ala Asp Val Leu Ala Asn
 85 90 95
 Ala Trp Arg Val Ser Pro Glu Glu Ala Arg Arg Val Lys Phe Asn Arg
 100 105 110
 Gln Glu Thr His Leu Ala Ser Thr Arg Gly Gln Ser Arg Ser Pro Gly
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 Arg Leu Asn Val Val Lys Glu Val Ile Asn Leu Leu Met
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 1 5 10

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<212> DNA

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18

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<211> 18

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<220>

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18

<210> 16

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<212> DNA

<213> Artificial Sequence

10/11

<220>

<223> Description of Artificial Sequence: Primer

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15

<210> 17

<211> 18

<212> DNA

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<223> Description of Artificial Sequence: Primer

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gatagaaccc acacgagc

18

<210> 18

<211> 29

<212> DNA

<213> Artificial Sequence

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<223> Description of Artificial Sequence: Primer

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<210> 19

<211> 6

<212> DNA

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<223> Description of Artificial Sequence: XbaI site

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6

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6

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32

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<211> 6

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<210> 24

<211> 29

<212> DNA

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<223> Description of Artificial Sequence: Primer

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29

<210> 25

<211> 6

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6

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 00/00988

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C12N15/82 A01H5/10 A01H5/00 C12N15/29

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, BIOSIS, MEDLINE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 18948 A (JAIN RAVINDER KUMAR ;THOMPSON ROBERTA GAIL (CA); CANADA NAT RES CO) 7 May 1998 (1998-05-07) cited in the application the whole document	1-3,6-9, 12,13
X	SAMMOUR REDA HELMY: "Proteins of linseed (Linum usitatissimum L.), extraction and characterization by electrophoresis." BOTANICAL BULLETIN OF ACADEMIA SINICA (TAIPEI), vol. 40, no. 2, April 1999 (1999-04), pages 121-126, XP000945031 ISSN: 0006-8063 the whole document	1-3,6-9, 12,13
-/-		



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

15 December 2000

Date of mailing of the international search report

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Bilang, J

INTERNATIONAL SEARCH REPORT

Inter national Application No

PCT/CA 00/00988

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>BORGMEYER J R ET AL: "ISOLATION AND CHARACTERIZATION OF A 25 KDA ANTIFUNGAL PROTEIN FROM FLAX SEEDS"</p> <p>BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS,</p> <p>vol. 187, no. 1, 1992, pages 480-487,</p> <p>XP000941778</p> <p>ISSN: 0006-291X</p> <p>the whole document _____</p>	<p>1-3, 6-9,</p> <p>12, 13</p>

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 00/00988

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9818948 A	07-05-1998	AU 4858897 A	22-05-1998
		GB 2332908 A	07-07-1999